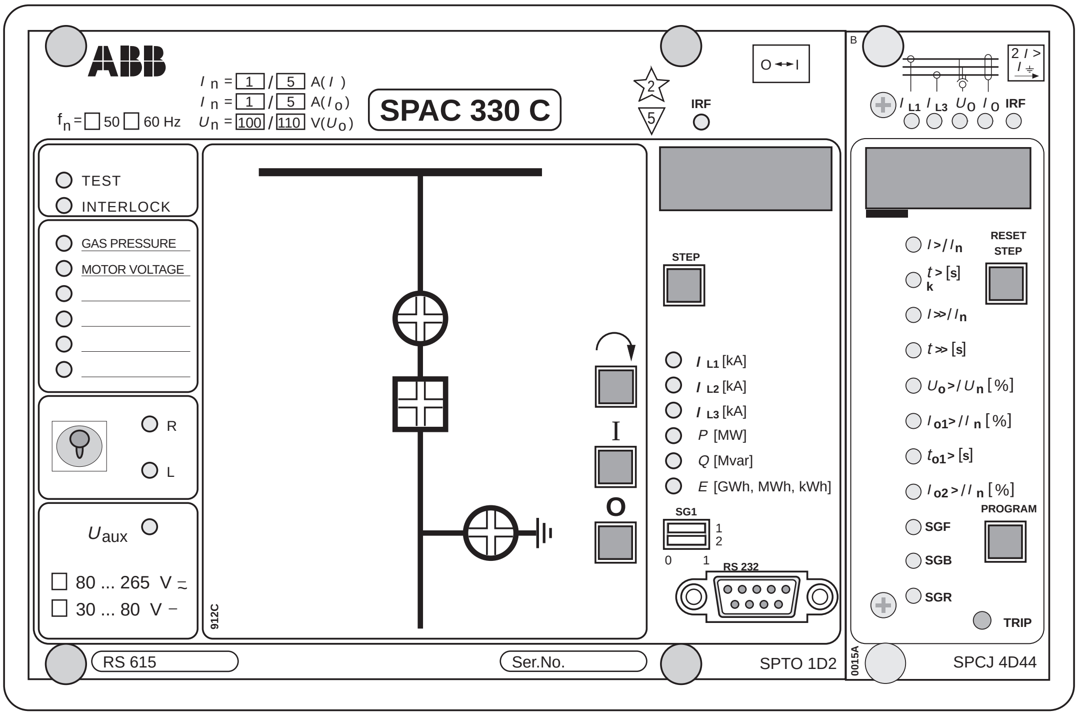
SPAC 330 C and SPAC 331 C Feeder terminals

User´s manual and Technical description



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SPAC 330 C and SPAC 331 C
Feeder terminals

Contents

The user's manual for the feeder terminals SPAC 330 C and SPAC 331 C is composed of the following partial manuals:

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General characteristics of D-type relay modules	1MRS 750066-MUM EN
Combined overcurrent and earth-fault relay module SPCJ 4D44	1MRS 750124-MUM EN

Features

Complete feeder terminal with a two-phase, two-stage overcurrent unit and a sensitive, two-stage directional earth-fault unit

Selectable definite time or inverse definite minimum time (IDMT) operation characteristic for the low-set stage of the overcurrent unit

Selectable instantaneous or definite time operation characteristic for the high-set stage of the overcurrent unit

Sensitive directional low-set earth-fault stage with definite time operation characteristic

Directional or non-directional high-set earth-fault stage

User-configurable feeder level interlocking system for preventing unpermitted switching operations

Local and remote status indication of three objects

Complete control module for local/remote control of one controllable object

Large library of pre-designed mimic diagram plates for presentation of the selected circuit-breaker/disconnector configuration

Six user-configurable binary inputs with local and remote indication

Phase current, energy, active and reactive power measurement and indication

Serial interface for connection of the feeder terminal to a substation level and network control level systems

Continuous self-supervision with auto-diagnostics for maximum reliability and availability

Area of application

The feeder terminals type SPAC 330 C and SPAC 331 C are designed to be used as cubicle-oriented protection and remote control interface units. In addition to protection, control and measurement functions the feeder terminals are provided with the data communication properties needed for the control of a feeder cubicle. Connection to higher level substation control equipment is carried out via a fibre-optical serial bus.

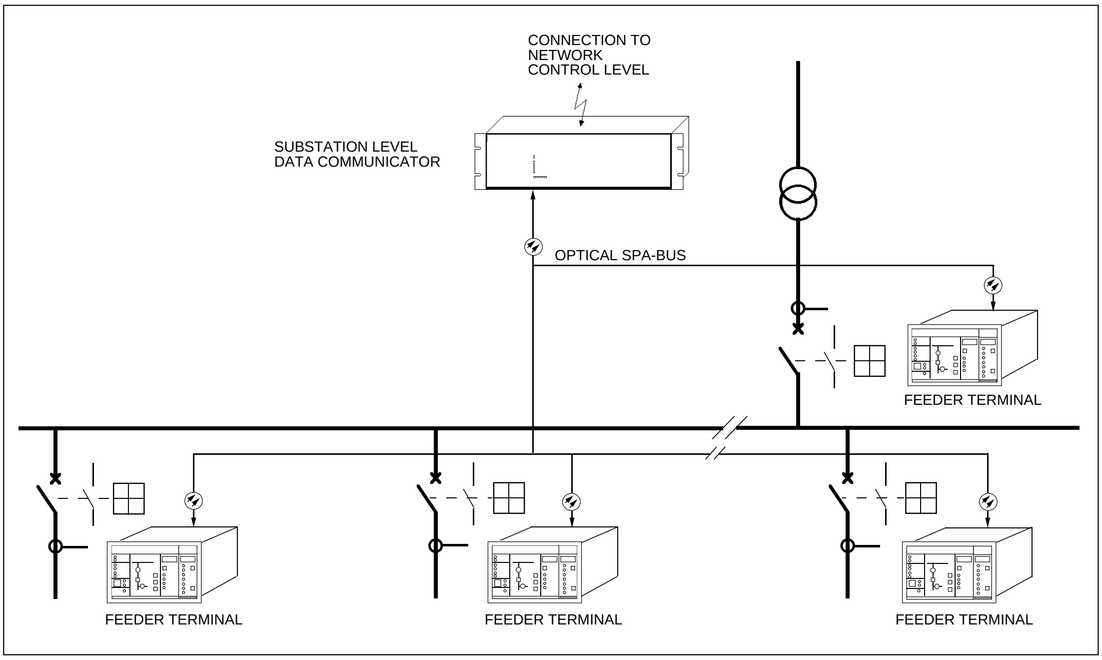


Fig. 1. Distributed protection and control system based on feeder terminals type SPAC 330 C and SPAC 331 C.

Regarding operational features the feeder terminals type SPAC 330 C and SPAC 331 C are identical. The only difference between the two types is the rated current of the earth-fault protection unit, see table below.

Feeder terminal type	Rated input currents OC unit	EF unit
SPAC 330 C	1 A, 5 A	1 A, 5 A
SPAC 331 C	1 A, 5 A	0.2 A, 1 A

The feeder terminals are intended for the selective short-circuit and directional earth-fault protection of radial feeders in solidly earthed, resistance earthed or impedance earthed power systems. The short-circuit and earth-fault protection is achieved by means of a combined overcurrent and earth-fault relay module.

The control module included in the feeder terminal indicates locally by means of LED indicators the status of 1 to 3 disconnectors or circuit breakers. Further the module allows status information from the circuit breaker and the disconnectors to be transmitted to the remote control system, and one object, e.g. a circuit breaker, to be opened and closed via the remote control system. The status information and the control signals are transmitted over the serial bus. Also local control of one object is possible by using the push-buttons on the front panel of the control module.

The control module measures and displays the three phase currents. The active and reactive power are measured over two mA-inputs. External measuring transducers are needed. Energy can be calculated on the basis of the measured power values or by using one binary input as an energy pulse counter. The measured values can be displayed locally and remotely as scaled values.

The protection relay module also measures and records the three phase currents and the neutral current. All the measured and recorded values are displayed locally and can be transmitted to the remote control system over the SPA bus.

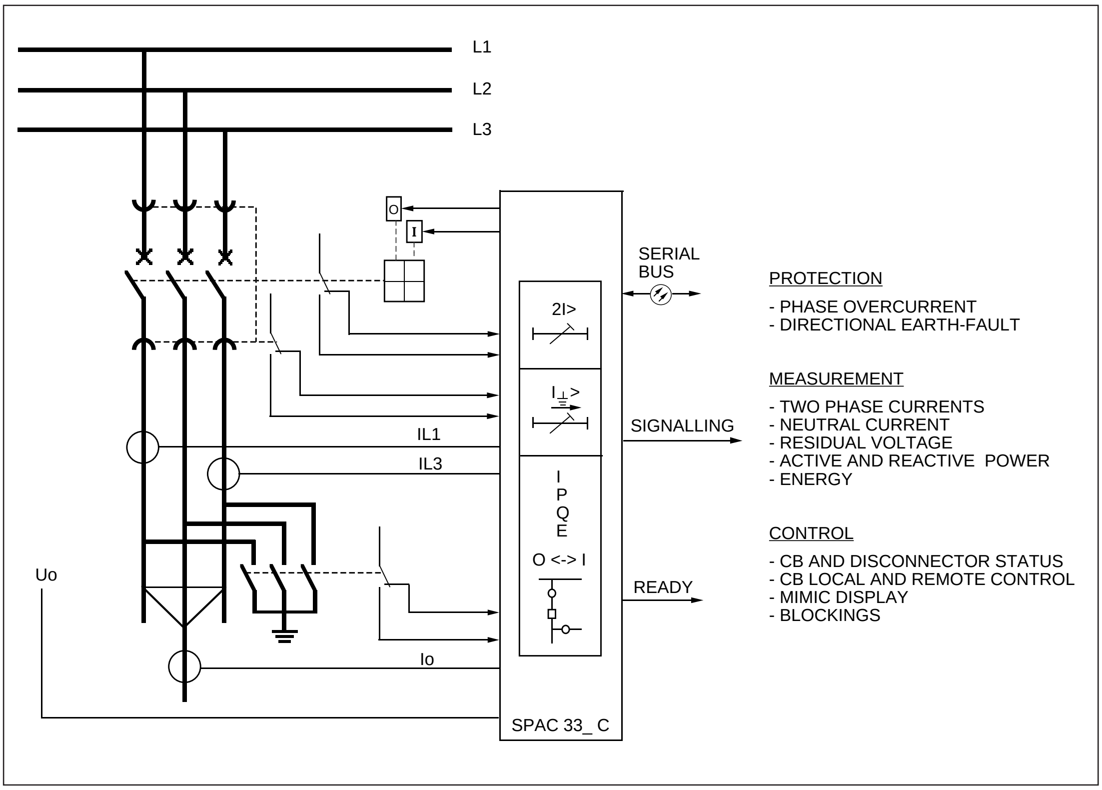


Fig. 2. Basic functions of the feeder terminals type SPAC 330 C and SPAC 331 C.

Description of function

Design

The feeder terminals type SPAC 330 C and SPAC 331 C include four withdrawable functional modules and one fixed functional module each. The main functions of the modules are specified in the following table.

Module	Function
Protection module SPCJ 4D44	Overcurrent and directional earth-fault protection. Two phase currents and the neutral current are measured, recorded and displayed locally and transmitted remotely
Control module SPTO 1D2	Reads and displays locally and remotely status data of maximum three disconnectors or circuit breakers Reads and displays locally and remotely up to six external binary signals Three phase currents, active and reactive power and energy are measured and displayed locally and remotely Transfers local or remote open and close commands for one circuit breaker
I/O module SPTR 3B12 or SPTR 3B13	Includes 12 optically isolated binary inputs, trip and close output relays and an IRF alarm output relay
Power supply module SPGU 240A1 or SPGU 48B2	Forms the internal voltages required by the other functional modules
Energizing input module SPTE 4F5 (SPAC 330 C) or SPTE 4F4 (SPAC 331 C)	Includes matching transformers and their tuning electronics for two phase currents and the neutral current and the residual voltage Includes the motherboard with three signalling output contacts and the electronics for the mA inputs

The combined phase overcurrent and directional earth-fault relay SPCJ 4D44 is a Euro-size (100 x 160 mm) withdrawable unit.

The control module type SPTO 1D2 is also withdrawable. The control module includes two PC boards; a CPU board and a front PC board which are joined together. The I/O board SPTR 3B_ is located behind the front PC board and is fastened by screws to the front PC board.

The power supply module SPGU 240A1 or SPGU 48B2 is located behind the front PC board of the control module and can be withdrawn from the case after the control module has been removed.

The protection relay module SPCJ 4D44 is fastened to the relay case by means of two finger screws and the control module type SPTO 1D2 by means of four finger screws. These modules are removed by undoing the finger screws and pulling the modules out of the aluminium case. To be able to remove the I/O module the control module has to be withdrawn from the case and the screws of the I/O module have to be removed from the front PC board.

The energizing input module SPTE 4F1 or SPTE 4F2 is located behind the front PC board of the control module on the left side of the case. A screw terminal block, the rear plate and the mother PC board are connected to the energizing input module.

The mother PC board contains the card connectors for the plug-in modules, the detachable multi-pole connector strips of the inputs and outputs, the tuning resistors of the secondary burden of the matching transformers and the electronics of the signal outputs and mA inputs.

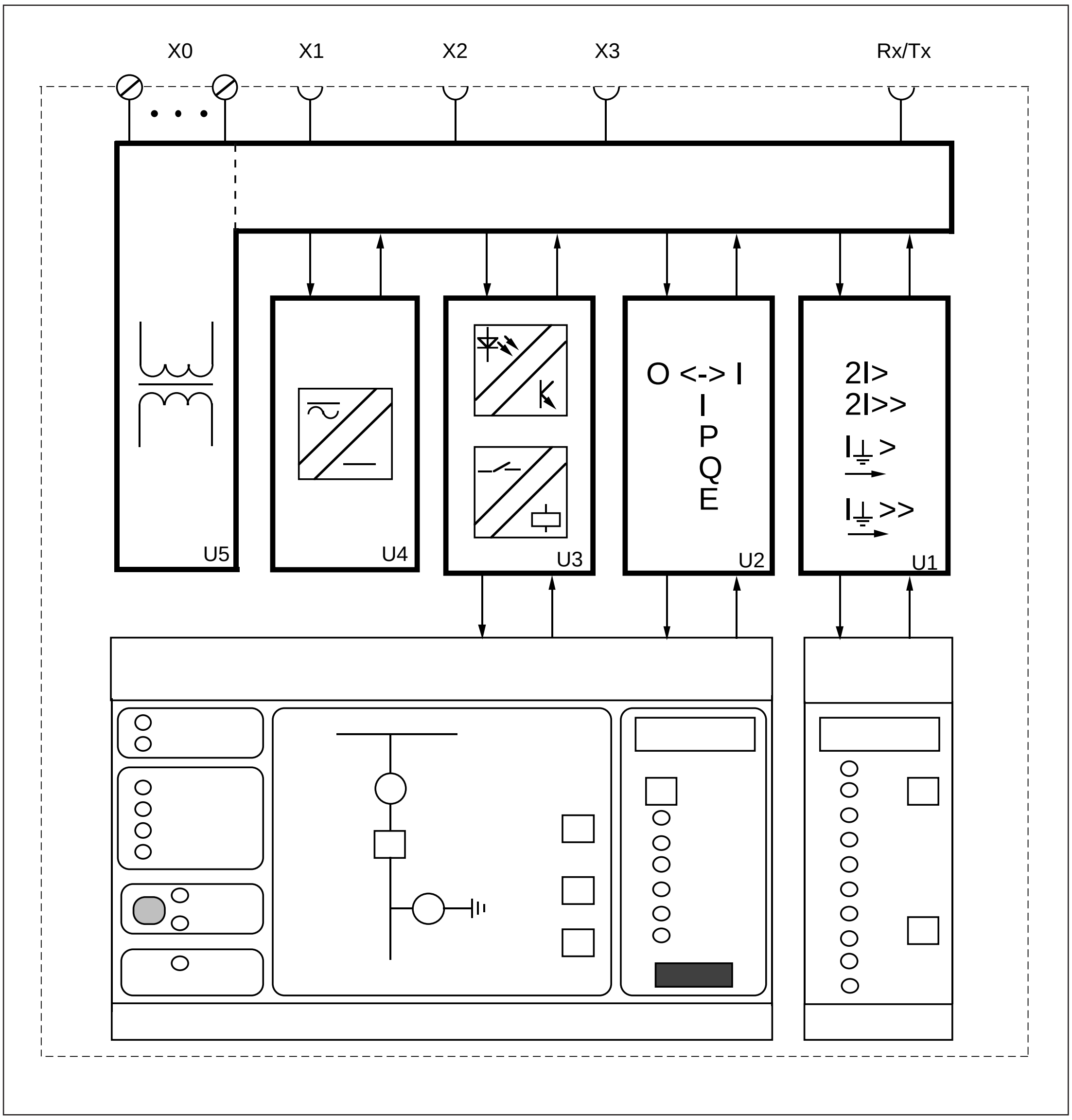


Fig. 3. Block diagram for the feeder terminals type SPAC 330 C and SPAC 331 C.

U1	Phase overcurrent and directional earth-fault relay module SPCJ 4D44
U2	Control module SPTO 1D2
U3	I/O module SPTR 3B12 or SPTR 3B13 for digital inputs and contact outputs
U4	Power supply module SPGU 240A1 or SPGU 48B2
U5	Energizing input module and motherboard SPTE 4F5 or SPTE 4F4
X0	Screw terminal strip
X1…X3	Multi-pole connector strips
Rx/Tx	Serial communication port

The case is made of an extruded aluminium profile, the collar is of cast aluminium and the cover of clear UV-stabilized polycarbonate. The collar is provided with a rubber gasket which allows an IP54 degree of protection by enclosure between the case and the mounting panel.

The cover of the case contains two push-buttons which can be used for scanning through the displays of the protection and control modules. To reset the operation indicators of the protection and to use the local control push-buttons of the control module, the front cover has to be opened.

The cover is locked with two finger screws which can be sealed to prevent unauthorized access to the front plate. The rubber gasket between the cover and the collar ensures that the cover, too, fulfills the IP54 requirements. The opening angle of the cover is 145°.

Protection functions

Phase overcurrent protection

The overcurrent unit of the combined overcurrent and directional earth-fault protection module SPCJ 4D44 has two operation stages, a low-set stage I> and a high-set stage I>>. The low-set stage may be given definite time or inverse definite minimum time (IDMT) characteristic, whereas the high-set stage can be given definite time characteristic only.

The module measures two of the phase currents of the protected feeder. When the phase current exceeds the set starting value of the low-set overcurrent stage, the overcurrent stage starts, simultaneously starting the corresponding timing circuit. When the set operation time has elapsed, a tripping command is delivered. Correspondingly the high-set overcurrent stage starts when its start value is exceeded. At the same time the high-set stage starts its timing circuit and trips when the set time has elapsed.

The operation of the low-set or the high-set overcurrent stages can be blocked by feeding an external control voltage to one of the external control inputs, i.e. input channel 8 or 9.

Directional earth-fault protection

The combined overcurrent and directional earth-fault protection module SPCJ 4D44 also includes a two-stage directional earth-fault unit.

The operation of the directional earth-fault unit is based on measuring the residual voltage, the neurtal current and the phase angle between these two quantities.

The earth-fault unit starts once the three criteria below are fulfilled:
- the residual voltage exceeds the set start level
- the earth-fault current exceeds the set start level
- the phase angle between residual voltage and earth-fault current is within the operation sector $\varphi_b \pm\Delta\varphi$, where φ_b is the characteristic basic angle of the network and $\Delta\varphi$ is the operation area.

When the residual voltage exceeds the set start value U_0> and the neutral current exceeds the set start value I_{01}> and the phase angle between the residual voltage and the neutral current is within the operation range, the low-set stage starts and its operation time t_{01}> starts running. When the set time has timed out the low-set stage delivers a tripping signal to the circuit breaker.

The high-set stage of the earth-fault unit operates in the same way when its set start value I_{02}> has been exceeded, but the high-set stage can be given eihter directional or non-directional mode of operation.

The energizing inputs of the earth-fault unit are equipped with low-pass filters which suppress harmonics in the energizing signals.

The tripping of the earth-fault stages can be blocked by feeding a control voltage to one of the external control inputs of the feeder protection unit, i.e. input channel 8 or 9.

Contact outputs of the protection

The tripping signal of the feeder terminal is wired to the OPEN output.The feeder terminal has four signalling contacts, one of which is the common internal relay failure (IRF) output. Three signalling outputs, SIGNAL 1…3, can be used to indicate starting or tripping of the protection, see chapter "Signal diagram".

Control functions

General

The control module SPTO 1D2 is used for reading status information from circuit breakers and disconnectors.The module indicates the status locally by means of LED indicators and transfers the information to the substation level via the fibre-optical SPA bus. The status of three objects can be indicated.

The control module is also used for controlling one object e.g. a circuit breaker, locally or with the opening or closing commands received over the SPA bus.

In addition to status information the control module can read other binary data, indicate the information locally and transfer it to the substation level equipment. Six external binary signals can be wired to the feeder terminal.

Input channels 1…3

The control module uses input channels 1…3 to read status information from circuit breakers and disconnectors. Each of these channels is formed by two binary inputs, one input is used for reading the open status and the other for reading the close status of an object. Thus the status information must be wired to the feeder terminal as four-pole information.

The front panel of SPTO 1D2 has a 4x4 matrix of status indication LEDs. Simultaneously, three of these LEDs can be used for status indication. The circuit breaker / disconnector configuration indicated by these LEDs is freely configurable by the user.

One of the objects whose status is read via input channels 1…3 can be controlled. This is done by using the outputs OPEN and CLOSE.

Input channels 4…9 and 10…13

The control module can be used for reading six external and four internal binary signals. The external signals, channels 4…9, can be single contact data wired from the bay and the internal signals, channels 10…13, are startings and trippings of the protection.

The input signal type for channels 4…13 can be programmed to be active at high state, i.e. normally open contact, or active at low state, i.e. normally closed contact.

The front panel has a local LED indication for the external input channels 4…9. The red LED is lit when the input is active.

The input channels 4…13 can be used to control the outputs OPEN, CLOSE and SIGNAL 1…3. If the input channel becomes active the programmed OPEN or CLOSE output gives a pulse. The output SIGNAL 1…3 is active as long as the input is active.

Interlocking

The control module includes a cubicle-based interlocking which is freely programmable by the user. When writing an interlocking program the user defines when it is allowed to give an open or close pulse for the controlled object. When an opening or closing command is given the interlocking program is checked and after that the command is executed or canceled.

The interlocking can be programmed to be depending on the status of the four-pole input channels 1…3 and the status of input channels 4…13. The tripping signals of the protection are not influenced by the interlocking.

To simplify start-up the feeder terminal is provided with default interlocking schemes. A default interlocking scheme is always related to a default circuit breaker / disconnector configuration.

Conditional output control

Normally the OPEN and CLOSE outputs are controlled by giving an open or close command. In the conditional output control all the outputs, i.e. OPEN, CLOSE and SIGNAL 1…3, can be controlled without using an open or close command. The outputs are activated in accordance with the interlocking program and the status of the input channels 1…3 and 4…13.

Measurement functions

The control module SPTO 1D2 and the combined overcurrent and directional earth-fault module SPCJ 4D44 both measure analog signals.

The combined overcurrent and directional earth-fault module measures two phase currents and the neutral current. The module displays the current values locally and transmits the information via the SPA bus to the remote control system. The protection module displays the measured values as multiples of the rated current of the feeder terminal.

The control module measures four analog signals; two phase currents and active and reactive power. The transforming ratio of the primary current transformers can be given to the control module. In this way display of pri- mary values of the phase currents is possible.

The control module measures the active and reactive power via two mA inputs. External measuring transducers have to be used. The mA signals are scaled to actual MW and Mvar values and the data is diplayed locally and can be transmitted to the remote control system.

Active energy is measured in two ways; either by calculating the value on the basis of the measured power or by using input channel 7 as a pulse counter. In the latter case an external energy meter with pulse output is needed. In both cases the amount of measured energy is displayed locally and can be transmitted to the remote control system.

Serial communication

The feeder terminal includes two serial communication ports, one on the front panel and the other on the rear panel.

The 9-pin RS 232 connection on the front panel is to be used for setting the feeder ter-minal and determining the CB/disconnector configuration, the feeder oriented interlocking and other parameters from a terminal or a PC.

The 9-pin RS 485 connection on the rear panel is used for connecting the feeder terminal to the SPA bus. A bus connection module type SPA-ZC 21 or SPA-ZC 17 has to be used.

Auxiliary power supply

For the operation of the feeder terminal a secured auxiliary voltage supply is needed. The power supply module SPGU240A1 or SPGU 48B2 forms the voltages required by the protection relay module, the control module and the input/ output module.

The power supply module is a transformer connected, i.e. galvanically isolated primary and secondary side, flyback-type dc/dc converter. The primary side of the power supply module is protected with a fuse located on the PCB of the control module.

A green LED indicator U_{aux} on the front panel is lit when the power supply module is in operation. There are two versions of power supply modules available. The secondary sides are identical, only the input voltage range is different. The input voltage range is indicated on the front panel of the control module.

Application

Mounting and dimensional drawings

The feeder terminal is housed in relay case which primarily is intended for flush mounting. The feeder terminal is fixed to the mounting panel by means of four galvanized sheet steel mounting brackets. The feeder terminal can also be semi-flush mounted by means of optional raising frames. A surface mounting case type SPA-ZX 316 is also available.

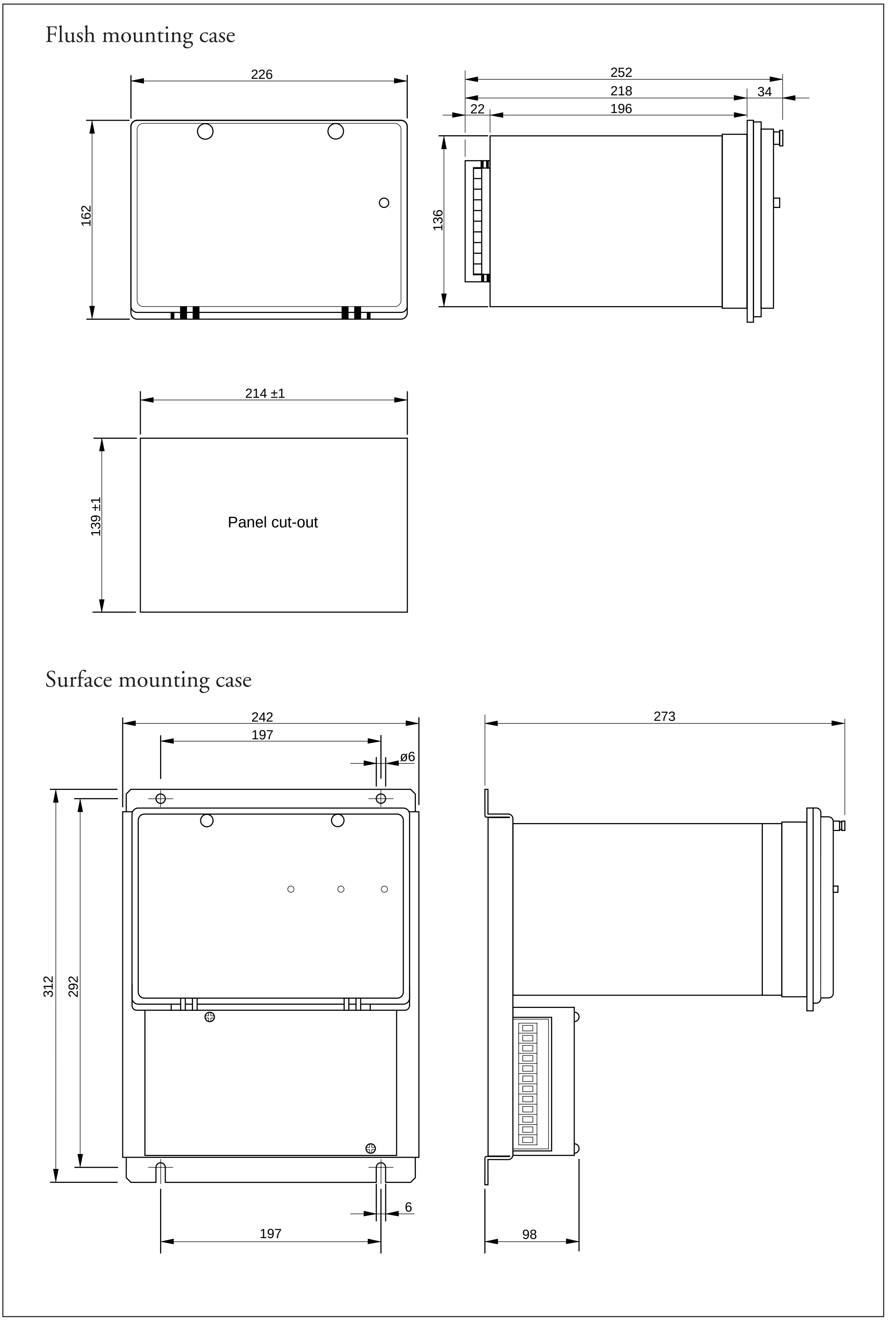


Fig. 4. Dimensional drawings for mounting cases of the feeder terminals type SPAC 330 C and type SPAC 331 C.

Connection diagram

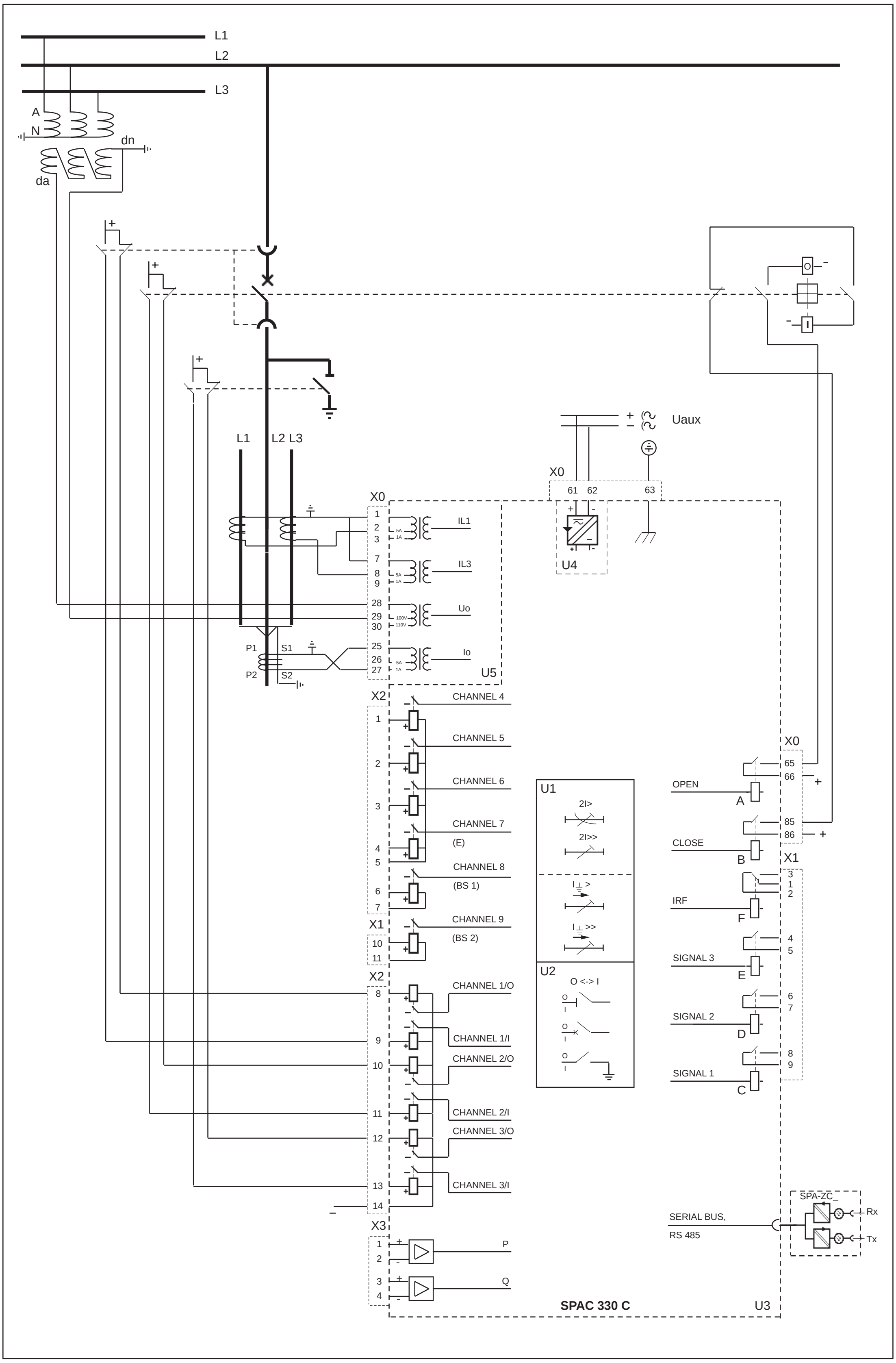


Fig. 5. Connection diagram for the feeder terminal type SPAC 330 C. The connection diagram of the feeder terminal type SPAC 331 C is identical with that of SPAC 330 C except for the rated current of the energizing inputs 25-26 and 25-27 which for the feeder terminal SPAC 331 C are 0.2 A and 1 A respectively.

Terminal numbers:

Terminal block	Terminal number	Function
X0	1-2	Phase current I_{L1}, 5A
	1-3	Phase current I_{L1}, 1A
	7-8	Phase current I_{L3}, 5A
	7-9	Phase current I_{L3}, 1A
	25-26	Neutral current I_0, 5A in SPAC 330 C or 1A in SPAC 331 C
	25-27	Neutral current I_0, 1A in SPAC 330 C or 0.2A in SPAC 331 C
	28-29	Residual voltage U_0, 100 V
	28-30	Residual voltage U_0, 110 V
	61-62	Auxiliary power supply. Positive voltage should be connected to terminal 61
	63	Equipment earth
	65-66	CB open output, as a default I>, I>>, I_{01}> and I_{02}> tripping signal
	85-86	CB close output
X1	1-2-3	Self-supervision (IRF) signalling output. When auxiliary power is connected and the device is operating properly the interval 2-3 is closed
	4-5	Signal output 3. E.g. I> alarm, I>> alarm, I_{01}> alarm, I_{02}> alarm (configurable), as a default alarm for I> or I>> trip
	6-7	Signal output 2. E.g. I> start or alarm, I>> start or alarm, I_{01}> start or alarm, I_{02}> start or alarm (configurable), as a default no signal is connected
	8-9	Signal output 1. E.g. I> start, I>> start, I_{01}> start, I_{02}> start (configurable), as a default I> start
	10-11	Input channel 9
X2	1-5	Input channel 4
	2-5	Input channel 5
	3-5	Input channel 6
	4-5	Input channel 7 or energy pulse counter
	6-7	Input channel 8 or blocking input for the protection
	8-14	Input channel 1, open status. E.g. when a circuit breaker is open there must be a voltage connected to this input
	9-14	Input channel 1, closed status. E.g. when a circuit breaker is closed there must be a voltage connected to this input
	10-14	Input channel 2, open status
	11-14	Input channel 2, closed status
	12-14	Input channel 3, open status
	13-14	Input channel 3, closed status
X3	1-2	mA input for the measurement of active power
	3-4	mA input for the measurement of reactive power

The channel numbers mentioned above are used when the control module SPTO 1D2 is to be configured. When the control module is configured the following codes are used for the outputs:

Output	Terminal numbers	Output code for interlocking	Output code for Conditional Output Control
OPEN	X0/65-66	20	220
CLOSE	X0/85-86	21	221
SIGNAL 1	X1/8-9	22	22
SIGNAL 2	X1/6-7	23	23
SIGNAL 3	X1/4-5	24	24

Signal diagram

The initial factory settings of the feeder terminal may have to be changed in different applications. The following diagram illustrates how the input and output signals can be configured to obtain the required functions for the feeder terminal.

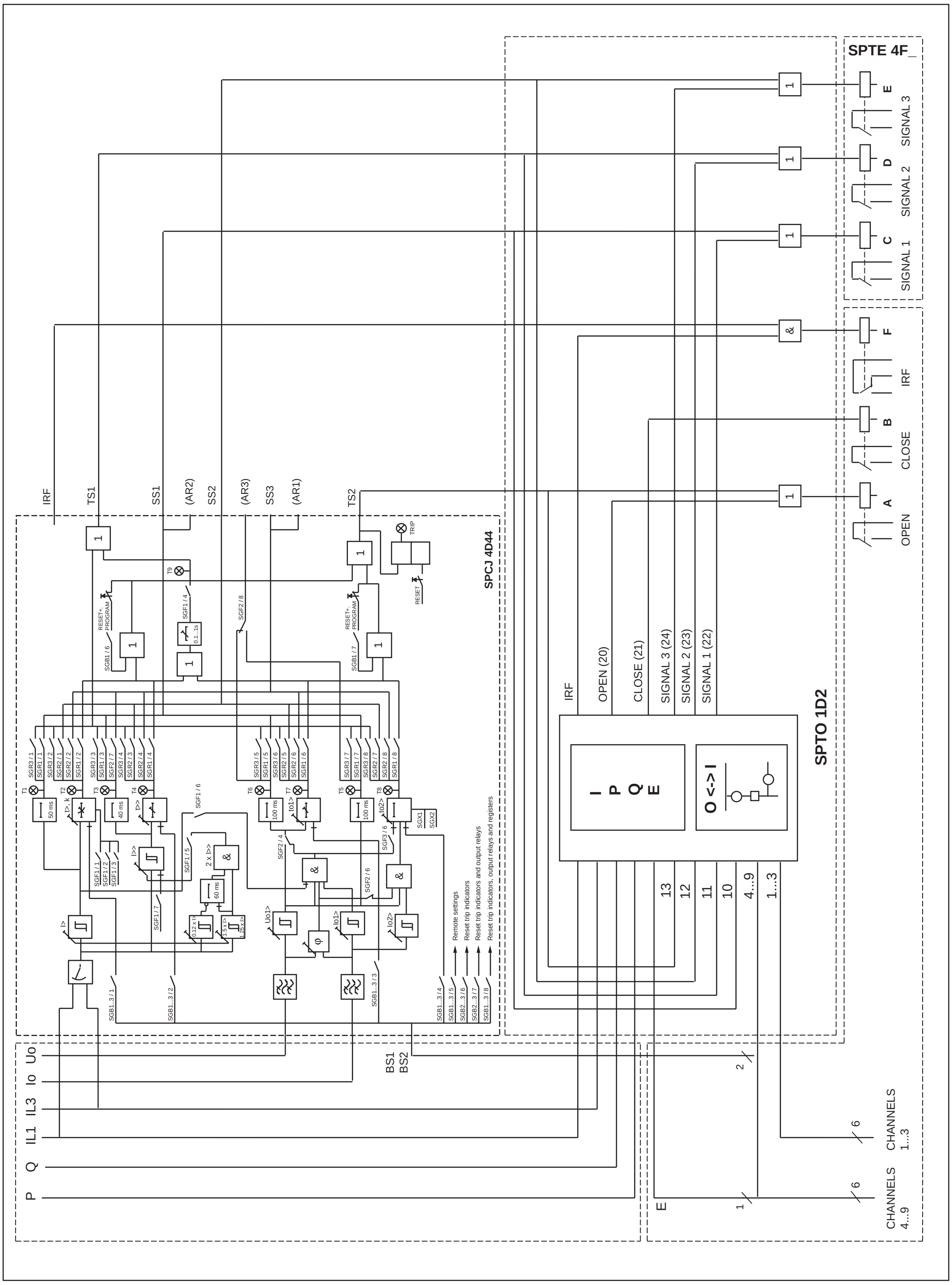


Fig. 6. Control signals between the modules of the feeder terminals type SPAC 330 C and type SPAC 331 C.

The following table gives the default values of the switches shown in Fig. 6.

Switch	Function	Default value
SGF1/1…3	Selection of operation characteristic for the I> stage	0
SGF1/4	Selection of circuit breaker failure protection	0
SGF1/5	Selection of automatic doubling of the set start value of stage I>> e.g. on energization of the protected object	0
SGF1/6	Blocking of stage I_{01}> by the start signal of stage I>	0
SGF2/4	Selection of directional function or non-directional residual voltage function of stage I_{01}>	0
SGF2/6	Selection of directional/non-directional function for stage I_{02}>	0
SGF2/7	No function in SPAC 330 C nor SPAC 331 C	0
SGF2/8	No function in SPAC 330 C nor SPAC 331 C	0
SGB1/1	Forms from a control voltage applied to input 8 a blocking signal for the tripping of the I> stage	0
SGB1/2	Forms from a control voltage applied to input 8 a blocking signal for the tripping of the I>> stage	0
SGB1/3	Forms from a control voltage applied to input 8 a blocking signal for the tripping of the I_{01}> stage	0
SGB1/4	Forms from a control voltage applied to input 8 a blocking signal for the tripping of the I_{02}> stage	0
SGB1/5	Enables switching from protection main settings to second settings by applying an eternal control voltage to input 8	0
SGB1/6	Selects a latching feature for the trip signal TS2 at overcurrent faults	0
SGB1/7	Selects a latching feature for the trip signal TS2 at earth faults	0
SGB1/8	Enables remote resetting of latched output relays and recored values by an external control voltage on input 8	0
SGB2/1…8	Identical with switches SGB1/1…8 but signal to input 9	0
SGR1/1	Routes the starting signal of stage I> to the SIGNAL 1 output	1
SGR1/2	Routes the tripping signal of stage I> to the OPEN output	1
SGR1/3	Routes the starting signal of stage I>> to the SIGNAL 1 output	0
SGR1/4	Routes the tripping signal of stage I>> to the OPEN output	1
SGR1/5	Routes the starting signal of stage I_{01}> to the SIGNAL 1 output	0
SGR1/6	Routes the tripping signal of stage I_{01}> to the OPEN output	1
SGR1/7	Routes the starting signal of stage I_{02}> to the SIGNAL 1 output	0
SGR1/8	Routes the tripping signal of stage I_{02}> to the OPEN output	1
SGR2/1	Routes the tripping signal of stage I> to the SIGNAL 3 output	1
SGR2/2	No function in SPAC 330 C nor SPAC 331 C	0
SGR2/3	Routes the tripping signal of stage I>> to the SIGNAL 3 output	1
SGR2/4	No function in SPAC 330 C nor SPAC 331 C	0
SGR2/5	Routes the tripping signal of stage Io> to the SIGNAL 3 output	0
SGR2/6	No function in SPAC 330 C nor SPAC 331 C	1
SGR2/7	Routes the tripping signal of stage Io>> to the SIGNAL 3 output	0
SGR2/8	No function in SPAC 330 C nor SPAC 331 C	1
SGR3/1	Routes the starting signal of stage I> to the SIGNAL 2 output	0
SGR3/2	Routes the tripping signal of stage I> to the SIGNAL 2 output	0
SGR3/3	Routes the starting signal of stage I>> to the SIGNAL 2 output	0
SGR3/4	Routes the tripping signal of stage I>> to the SIGNAL 2 output	0
SGR3/5	Routes the starting signal of stage I_{01}> to the SIGNAL 2 output	0
SGR3/6	Routes the tripping signal of stage I_{01}> to the SIGNAL 2 output	0
SGR3/7	Routes the starting signal of stage I_{02}> to the SIGNAL 2 output	0
SGR3/8	Routes the tripping signal of stage I_{02}> to the SIGNAL 2 output	0

Terminals
and wiring

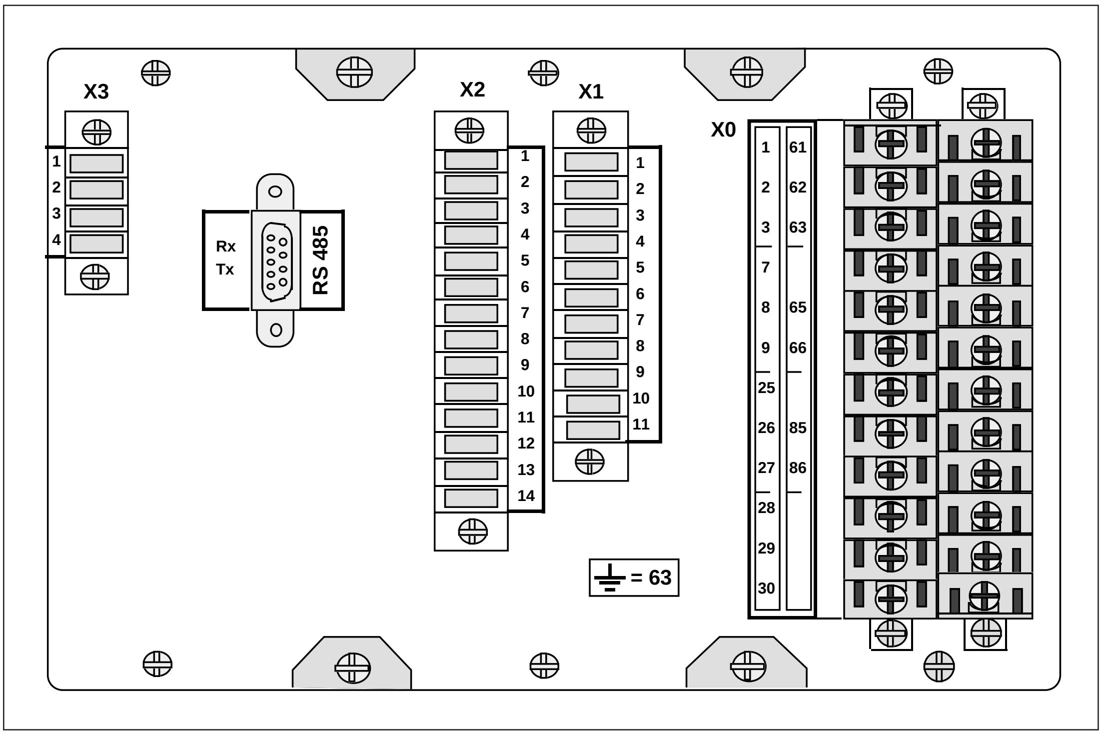


Fig. 7. Rear view of the feeder terminals type SPAC 330 C and type SPAC 331 C.

All external conductors are connected to the terminal blocks on the rear panel. The terminal block X0 is a fix-mounted screw terminal block which has been attached to the energizing input module. The connectors X1…X3 are detachable-type multi-pole connector strips equally with screw terminals.

The male part of the multi-pole connector strips are attached to the mother PC board. The counter parts of the detachable terminals are delivered as loose parts together with the feeder terminal. The position of the counter part can be secured by means of fixing accessories and screws at the ends of the connector.

The measuring signal inputs, auxiliary voltage supply and OPEN and CLOSE contact outputs are connected to the terminal block X0. Each terminal is dimensioned for one 4 mm^2 or two 2.5 mm^2 wires. The pilot wires are fastened with M 3.5 Phillips cross-slotted screws, recess type H. The terminal block is protected by a transparent shroud.

The signalling contact outputs are connected to the multi-pole connector X1. The input channels 1…3 and 4…8 are connected via connector X2. Input channel 9 is wired via connector X1 and the two mA inputs via connector X3. One max. 1.5 mm^2 wire or two max. 0.75 mm^2 wires can be connected to one screw terminal.

The rear panel of the feeder terminal is provided with a serial interface for the SPA bus (Rx/Tx). The SPA bus is connected by means of connection module type SPA-ZC7 which is fitted to the 9-pole D-type subminiature connector. The connection module is fastened to the rear panel with the screws included in the delivery of the module.

The 9-pole D-type subminiature connector INTERLOCK is reserved for future use.

Start-up

The start-up of the feeder terminal should be done in accordance with to the following instructions. Checks1 and 2 have to be performed before the auxiliary power supply is switched on.

1. Control voltage ranges of the binary inputs

Before connecting a voltage to input channels 1…9, check the permitted control voltage range of the inputs. The voltage range, U_{aux}, is indicated on the front panel of the control module.

2. Auxiliary supply voltage

Before switching on the auxiliary supply voltage check the permitted input voltage range of the power supply module. The voltage range, U_{aux}, is indicated on the front panel of the control module.

3. Configuration of the control module SPTO 1D2

All the non-volatile EEPROM parameters have been given default values after factory testing. The "Configuration and interlocking scheme No. 1" has been selected. The default parameter values are shown in the manual of the control module SPTO 1D2.

If the default parameters are not satisfactory, the following parameters can be programmed:
- Configuration; default configuration or user-defined configuration
- Interlocking; default interlocking or user-defined interlocking
- OPEN and CLOSE outputs; pulse lengths
- Measurements; ratio of primary current transformers, settings for active and reactive power measurement, settings for energy measurement
- Input channels 4…13; settings for polarity and output activation
- Event reporting; event masks, event delay times

The programming can be done via the front panel RS 232 port or the rear panel RS 485 port by using the SPA protocol. Instructions are given in the manual of the control module SPTO 1D2.

4. Settings of the relay module SPCJ 4D44

The protection module has been given default setting values at the factory. All the current and time parameters are set at their minimum values. The default checksum values for the switchgroups are:

Switchgroups	Σ (checksums)
SGF1	0
SGF2	0
SGF3	0
SGB1	0
SGB2	0
SGB3	0
SGR1	171
SGR2	165
SGR3	0

All tripping signals I>, I>>, I_{01}> and I_{02}> are connected to the signal TS2, which controls the OPEN output. The signal SS1 which controls the SIGNAL 1 output indicates starting of the I> stage. The signal SS2 which controls the SIGNAL 3 output indicates tripping of the I> and I>> stages.

These values can be changed manually from the push-buttons on the front panel of the protection module. Also the RS 232 interface on the front panel of the control module or the RS 485 interface on the rear panel of the feeder terminal can be used for changing the settings of the protection. In that case SPA protocol commands are used.

The exact meaning of the switchgroups is explained in the manual of the combined overcurrent and directional earth-fault relay module SPCJ 4D44.

Technical data

Energizing inputs

Rated currents I_n			
- overcurrent unit of SPAC 330 C and SPAC 331 C		1 A	5 A
- phase current inputs		X0/1-3, 7-9	X0/1-2, 7-8
- earth-fault unit of SPAC 330 C		1 A	5 A
- neutral current inputs		X0/25-27	X0/25-26
- earth-fault unit of SPAC 331 C	0.2 A	1 A	
- neutral current inputs	X0/25-27	X0/25-26	
Thermal withstand capability			
- continuous	1.5 A	4 A	20 A
- for 1s	20 A	100 A	500 A
Dynamic current withstand,			
- half-wave value	50 A	250 A	1250 A
Input impedance	<750 mΩ	<100 mΩ	<20 mΩ
Residual voltage inputs	X0/28-29	X0/28-30	
Rated voltage U_n	100 V	110 V	
Continuous withstand	2 x U_n	2 x U_n	
Burden at rated voltage	<0.5 VA		
Rated frequency f_n	50 Hz or 60 Hz		

mA inputs

Terminal numbers	
-active power	X3/1-2
-reactive power	X3/3-4
Input current range	-20…0…20 mA

Binary inputs

Terminal numbers	
- channels 1…3, four-pole inputs	X2/8-14, 9-14, 10-14, 11-14, 12-14, and 13-14
- channels 4…9, single-contact inputs	X2/1-5, 2-5, 3-5, 4-5, 6-7 and X1/10-11
Input voltage range	
- input module type SPTR 3B12	80…265V dc
- input module type SPTR 3B13	30…80 V dc
Current drain, approx.	2 mA

Energy pulse counter input (input channel 7)

Terminal numbers	X2/4-5
Maximum frequency	25 Hz
Input voltage range	
- input module type SPTR 3B12	80…265V dc
- input module type SPTR 3B13	30…80 V dc
Current drain, approx.	2 mA

Blocking input (input channel 8 and 9)

Terminal numbers	X2/6-7
Input voltage range	
- input module type SPTR 3B12	80…265V dc
- input module type SPTR 3B13	30…80 V dc
Current drain, approx.	2 mA

Contact outputs

Control output numbers	X0/65-66 and 85-86
- rated voltage	250 V ac or dc
- continuous carry	5 A
- make and carry for 0.5 s	30 A
- make and carry for 3 s	15 A
- breaking capacity for dc, when the control circuit time constant L/R≤ 40 ms at the control voltage levels 48/110/220 V dc	5 A/3 A/1 A
- control output operating mode, when operated by the control module	pulse shaping
- control pulse length	0.1…100 s
Signalling output numbers	X1/1-2-3, 4-5, 6-7 and 8-9
- rated voltage	250 V ac or dc
- continuous carry	5 A
- make and carry for 0.5 s	10 A
- make and carry for 3 s	8 A
- breaking capacity for dc, when the control circuit time constant L/R≤ 40 ms at the control voltage levels 48/110/220 V dc	1 A/0.25 A/0.15 A

Auxiliary supply voltage

Type of built-in power supply module and supply voltage range	
- type SPGU 240A1	80...265 V ac or dc
- type SPGU 48B2	18...80 V dc
Burden of auxiliary supply under quiescent/ operating conditions	~10 W / ~15 W

Combined overcurrent and earth-fault module SPCJ 4D44

See "Technical Data" for the relay module

Control module SPTO 1D2

Control functions
- status indication for maximum three objects (e.g. circuit breakers, disconnectors, earth switches)
- user configurable configuration
- remote or local control (open and close) for one object
- feeder-based user-configurable interlocking scheme

Measurement functions
- phase currents, measuring range 0…2.5 x I_n
- phase current measuring accuracy better than ±1 % of I_n
- active and reactive power measurement via mA-inputs, external measuring transducers are needed
- mA measuring input current range -20…0…20 mA
- power measuring accuracy better than ±1 % of maximum value of measuring range
- energy measurement via pulse counter input or by calculating of measured power
- local and remote reading of measured data as scaled values

Data communication

Rear panel	
- connection	RS-485, 9-pin, female
Bus connection module with external supply	
- for plastic fibre cables	SPA-ZC 17 BB2_
- for plastic/glass fibre cables	SPA-ZC 17 BM2_
- for glass/plastic fibre cables	SPA-ZC 17 MB2_
- for glass fibre cables	SPA-ZC 17 MM2_
Bus connection module without external supply	
- for plastic fibre cables	SPA-ZC 21 BB
- for plastic/glass fibre cables	SPA-ZC 21 BM
- for glass/plastic fibre cables	SPA-ZC 21 MB
- for glass fibre cables	SPA-ZC 21 MM
Front panel	
- connection	RS 232, 9-pin, female
Data code	ASCII
Selectable data transfer rates	4800 or 9600 Bd

Insulation Tests *)

Dielectric test IEC 60255-5	2 kV, 50 Hz, 1 min
Impulse voltage test IEC 60255-5	5 kV, 1.2/50 μs, 0.5 J
Insulation resistance measurement IEC 60255-5	>100 MΩ, 500 Vdc

Electromagnetic Compatibility Tests *)

High-frequency (1 MHz) burst disturbance test IEC 60255-22-1	
- common mode	2.5 kV
- differential mode	1.0 kV
Electrostatic discharge test IEC 60255-22-2 and IEC 61000-4-2	
- contact discharge	6 kV
- air discharge	8 kV
Fast transient disturbance test IEC 60255-22-4 and IEC 61000-4-4	
- power supply	4 kV
- I/O ports 2 kV	

Environmental Conditions

Specified service temperature range	-10...+55°C
Transport and storage temperature range	-40...+70°C
Temperature influence on the operating values of the relay over the specified service temperature range	<0.2%/°C
Damp heat test, cyclic IEC 60068-2-30	+25...55°C, r.h. > 93%, 6 cycles
Degree of protection by enclosure of the relay case when panel mounted	IP 54
Weight of fully equipped relay	~5 kg

*) The tests do not apply to the serial port, which is used exclusively for the bus connection module.

Exchange and spare parts

Control module	SPTO 1D2
Combined overcurrent and earth-fault module	SPCJ 4D44
I/O module, input voltage range 80…265 V dc	SPTR 3B12
I/O module, input voltage range 30…80 V dc	SPTR 3B13
Power supply module, 80…265 V ac or dc	SPGU 240A1
Power supply module, 18…80 V dc	SPGU 48B2
Housing without plug in modules, SPAC 330 C	SPTK 4F5
Housing without plug in modules, SPAC 331 C	SPTK 4F4
Bus connection module with external supply	
- for plastic fibre cables	SPA-ZC 17 BB2_
- for plastic/glass fibre cables	SPA-ZC 17 BM2_
- for glass/plastic fibre cables	SPA-ZC 17 MB2_
- for glass fibre cables	SPA-ZC 17 MM2_
Bus connection module without external supply	
- for plastic fibre cables	SPA-ZC 21 BB
- for plastic/glass fibre cables	SPA-ZC 21 BM
- for glass/plastic fibre cables	SPA-ZC 21 MB
- for glass fibre cables	SPA-ZC 21 MM

Maintenance and repairs

When the protection relay is operating under the conditions specified in the section "Technical data", the relay is practically maintenance-free. The relay modules include no parts or components subject to an abnormal physical or electrical ware under normal operation conditions.

If the environmental conditions at the relay operation site differ from those specified, as to temperature and humidity, or, if the atmosphere around the relay contains chemically active gases or dust, the relay should be visually inspected in association with the relay secondary test being performed. At the visual inspection the following things should be noted:

- Check for signs of mechanical damage on relay case or terminals
- Check for dust inside the relay case or the cover of the relay case; remove by blowing pressurized air carefully
- Check for rust spots or signs of erugo on terminals, relay case or inside the relay.

If the relay fails in operation or if the operation values differ too much from those of the relay specifications the relay should be given a proper overhaul. Minor measures can be taken by personnel from the operator's instrument workshop but all major measures involving overhaul of the electronics are to be taken by the manufacturer. Please, contact the manufacturer or his nearest representative for further information about checking, overhaul and recalibration of the relay.

Note!
Static protection devices are measuring instruments which should be handled with care and protected against moisture and mechanical stress, especially during transport.

Order information

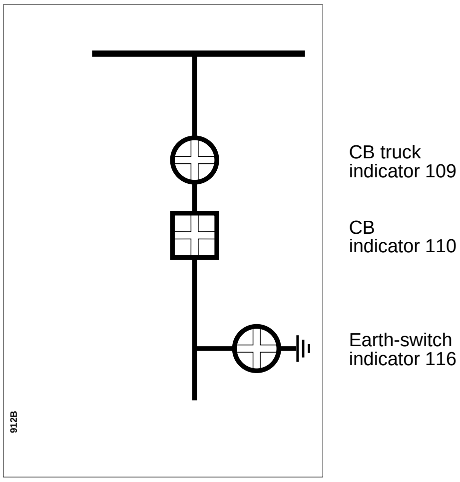
The following information should be given when ordering feeder terminals.

1. Quantity and type designation	15 units SPAC 330 C
2. Rated frequency	f_n= 50 Hz
3. Auxiliary supply voltage	U_{aux}=110 V dc
4. Type designation of the configuration plate	SYKK 912
5. Accessories	15 interface modules SPA-ZC 21_ _

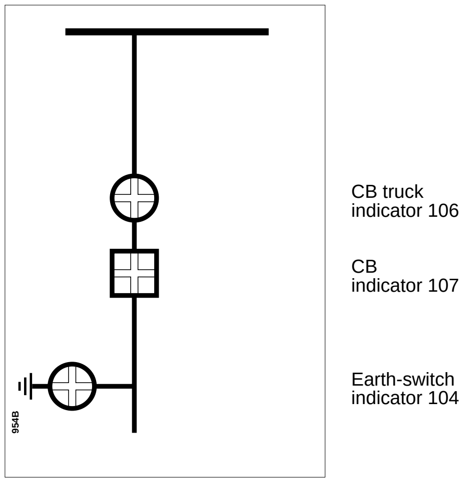
Four empty legend text films SYKU 997 for channel 4…9 indication are included in the feeder terminal delivery.

As different configuration plates are available for the feeder terminals SPAC 330 C and SPAC 331 C the type designation of the configuration plate should be stated in the order.

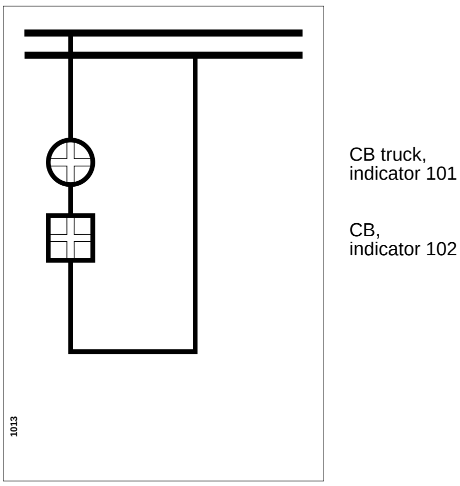
There are two parallel configuration plates for one circuit breaker/disconnector configuration; in the first type the closed status is indicated by red colour and open status by green colour, in the second type the colours are the opposite. The following standard configuration plates are available.



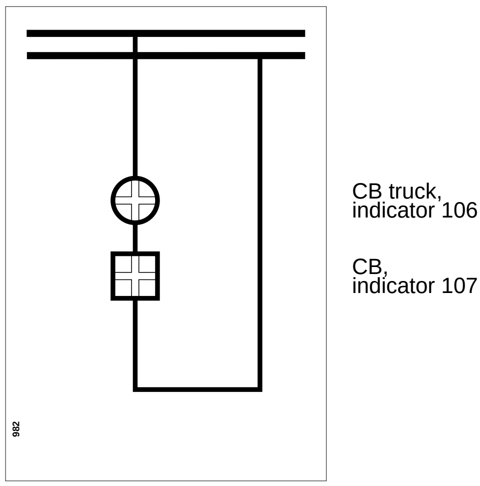
Configuration plate type SYKK 912
Open position = green
Close position = red



Configuration plate type SYKK 954
Open position = red
Close position = green



Configuration plate type SYKK 1013
Open position = green
Close position = red



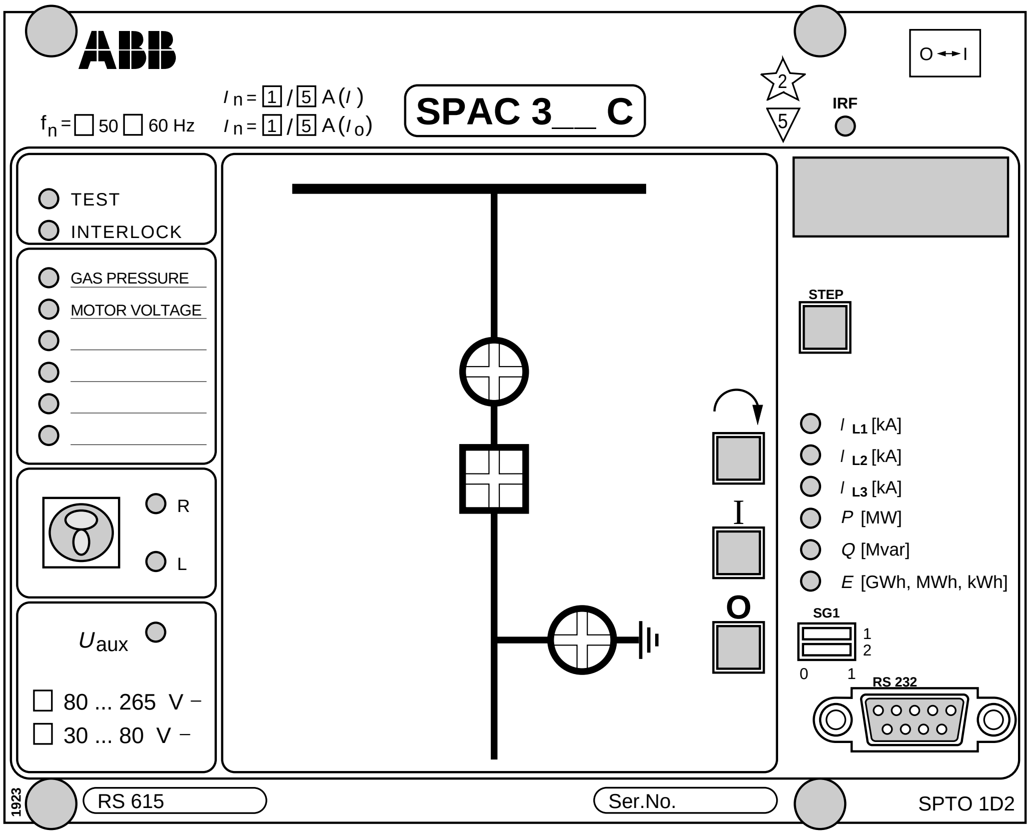
Configuration plate type SYKK 982
Open position = red
Close position = green

Fig. 8. Standard configuration plates for the feeder terminals SPAC 330 C and SPAC 331 C.

Note! On delivery the control module is given the "Configuration and interlocking scheme No. 1", regardless of the type of configuration plate delivered with the control module.

SPTO 1D2
Control module

User´s manual and Technical description



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SPTO 1D2
Control module

Contents

Description of functions

Control functions

The control module type SPTO 1D2 reads binary input signals and indicates the status of these signals locally and remotely. The control module also performs OPEN and CLOSE commands.

The input channels 1…3 are used for reading status information of circuit breakers and disconnectors (objects). Each of these channels includes two physical inputs, one for object open and one for object closed information.The module indicates the status information locally on the front panel by means of LED indicators and transfers the information to station level equipment via the SPA bus.

The control module is able to read the status information of maximum 3 objects. The front panel has a matrix of status indication LEDs. The configuration indicated by these LEDs is freely programmable by the user.

Input channels 4…13 consist of one physical binary input. These channels are used mainly to transfer binary signals other than circuit breaker and disconnector status information over the SPA bus to the remote control system. There is a local LED indication for the input channels 4…9 on the front panel.

The control module is able to give OPEN and CLOSE commands for one object. The commands may be given by means of the local push-buttons, via the SPA bus or the input channels 4…13. The output is a pulse with programmable pulse lenght.

An enable signal must be given by an interlocking program before the OPEN or CLOSE output pulse can be activated. The enable signal is given on the basis of the status of input channels 1…3 and 4…13 and the programmed logic.

The signalling outputs, SIGNAL 1…3, can be used to indicate the status of input channels 4…13. The selected output is active as long as the input channel is active.

The outputs OPEN, CLOSE or SIGNAL1…3 can be controlled by the conditional direct output control program. The program is similar to that of interlocking. The user can define when an output is to be activated. This is depending on the status of inputs 1…3 and 4…13 and the programmed logic. The output is active as long as the program gives the output signal.

Measurement functions

The control module SPTO 1D2 is able to measure three phase currents and two mA signals. The mA inputs are used for measuring active and reactive power. External measuring transducers are needed.

Input channel 7 can be used as a pulse counter for energy pulses. Energy can also be calculated on the basis of the measured power.

The measured signals can be scaled and they are indicated locally and over the SPA bus as actual values.

Block diagram

Simplified block diagram of the control module SPTO 1D2 is shown in Fig. 1.

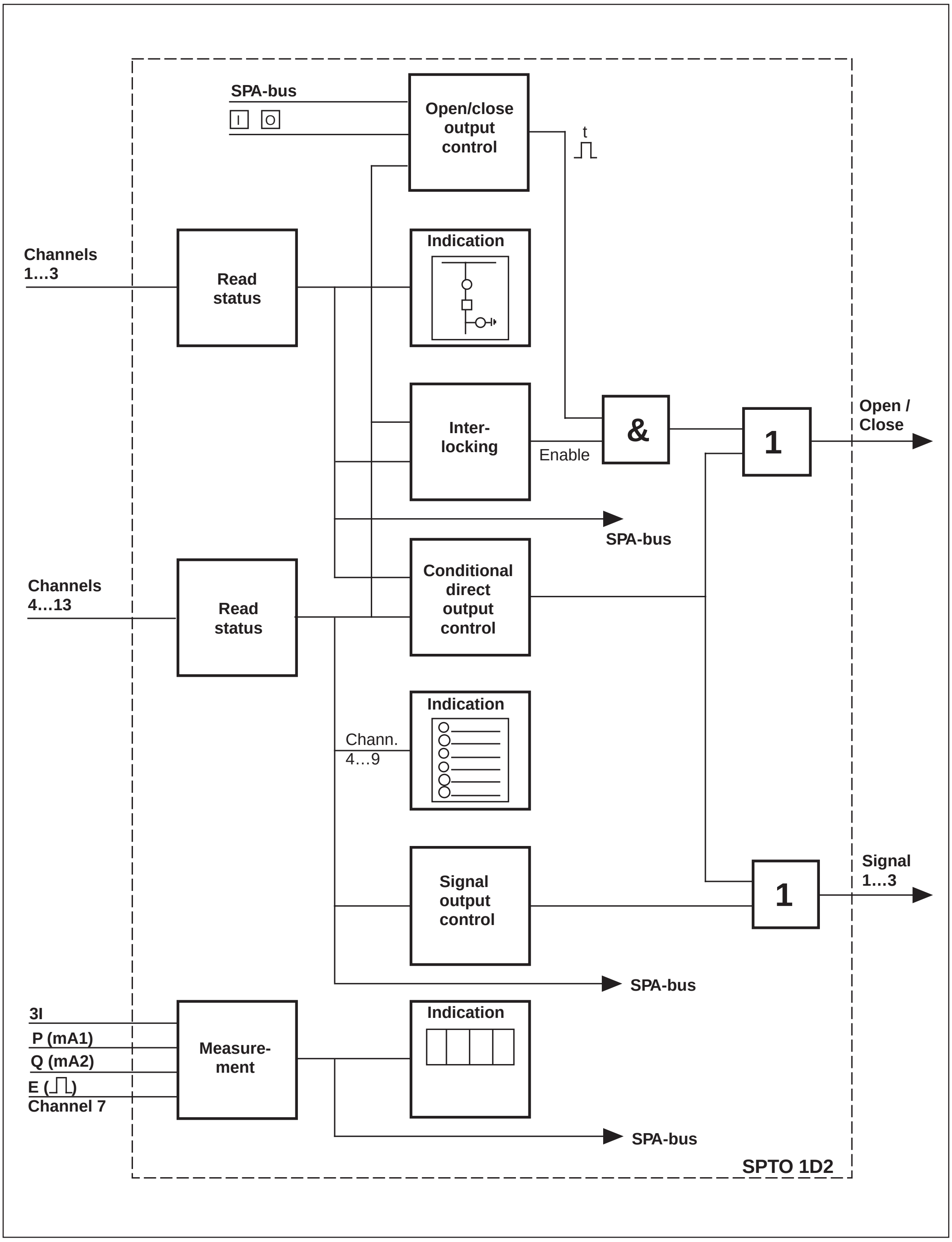


Fig. 1. Block diagram of the control module SPTO 1D2.

Front panel

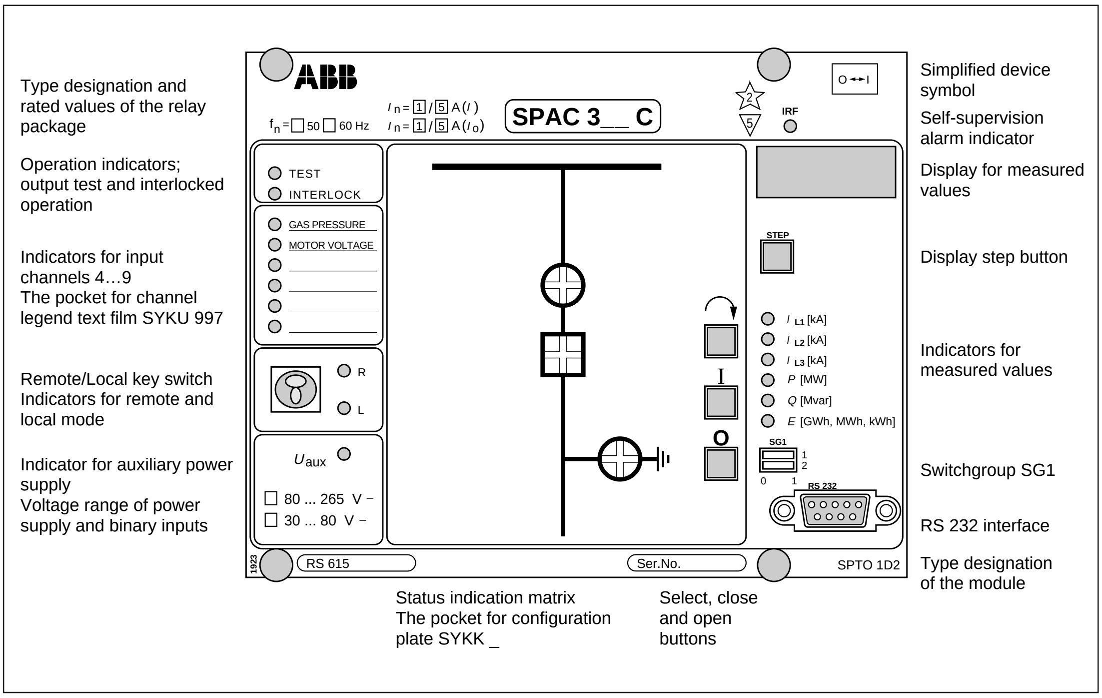


Fig. 2. Front panel of the control module SPTO 1D2 without the configuration plate SYKK __ and the channel legend text foil SYKU 997.

Object status indicators

The front panel has 16 LED indicators for local status indication. The indicators are arranged as a 4 x 4 matrix. Three of these indicators can be used simultaneously in the control module SPTO 1D2. The combination of indicators used is freely programmable by the user, see chapter "Configuration".

In front of the indicators there is a pocket for a separate plastic configuration plate type SYKK_. The bottom of the pocket is open. By changing the configuration plate and programming a new indicator combination different kinds of bays can be described.

The circuit breakers and disconnectors of the bay are shown on the configuration plate. The configuration plate has a transparent window in front of the indicators that are in use. The unused indicators are hidden.

One object indicator is composed of four LEDs, two vertical and two horizontal. Two of the LEDs are red and two are green. The red LEDs are vertical and the green LEDs horizontal in columns 1 and 3, see Fig. 6. In the columns 2 and 4 the green LEDs are vertical and the red LEDs horizontal. Due to this system both colours can be used to indicate either open or closed status.

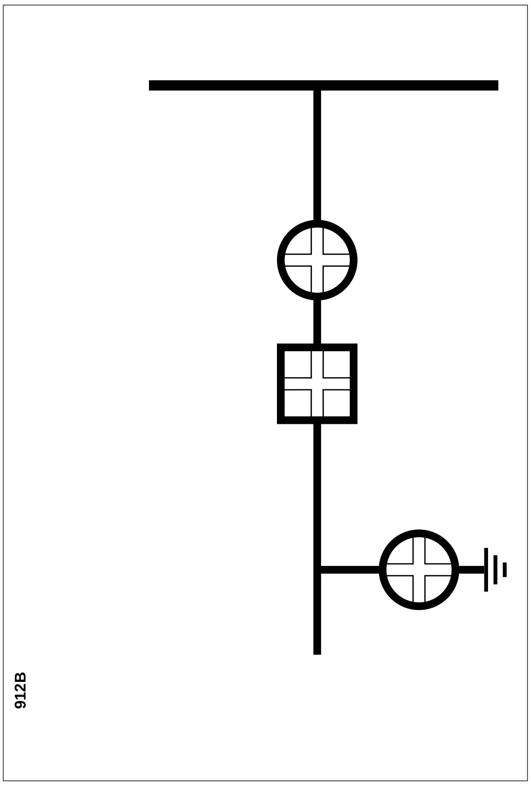


Fig. 3. Example of plastic configuration plate SYKK _. The size of the plate is 72 x 106.5 mm.

Indicators for input channels 4…9

The status of the input channels 4...9 is indicated locally on the front panel. Channel 4 refers to the upmost red indicator and channel 9 to the lowest one.

An input can be defined to be active at high state (NO contact) or active at low state (NC contact). The LED is lit when the input is active.

The indication of the active status of the input channels 4…9 can separately be programmed to be memory controlled. If an input channel indicator is memory controlled the LED indicator remains lit until the channel is locally reset by pressing the push-buttons STEP and SELECT simultaneously or by remote control via the serial interface using the parameter S5, which is given the value 0 or 1.

The front panel has a pocket for a text legend foil, SYKU 997, on which the user can write the desired input legend text. The left side of the pocket is open. An empty text legend foil is delivered with the relay package.

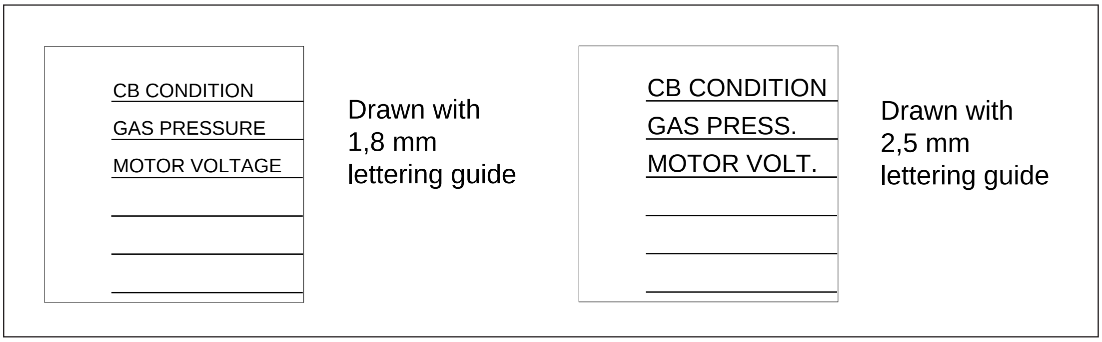


Fig. 4. Example of text legend foil SYKU 997. The foil is shown in actual size, width 33.5 mm and height 34 mm.

Operation indicators

The control module includes two red operation indicators showing the status of the module itself. These LEDs are normally dark. The indicators have the following function:

Indicator	Function
TEST	Is lit when the switch SG1/1=1. Then the interlockings are out of use
INTERLOCK	Is lit when a local control command is given and the operation of an object is inhibited by the interlocking program. This LED can be switched off by pressing the SELECT push-button or it is automatically switched off after a timeout of about 30 seconds When the control module is in the programming mode and the interlockings are in use the indicator lights and it is switched off when the operation mode is entered or when the interlockings are set out of use.

The green indicator U_{aux} indicates that an external power supply voltage is connected and the power supply module of the unit is operating. The input voltage range of the digital inputs and the power supply module is marked below the U_{aux} indicator.

REMOTE/LOCAL key switch

To be able to use the local OPEN and CLOSE push-buttons, the key switch must be in the position LOCAL, indicated by the yellow LED L. All remote controls via the serial communication are inhibited, but control operations via input channels 4…13 or control operations by the conditional direct output control function are allowed.

Accordingly, to be able to control an object via the serial communication, the key switch must be in the REMOTE position indicated by the yellow LED R. When the key switch is in the REMOTE position, local push-button controls are inhibited.

The key can be removed both in local and in remote position.

∩ , I and O push-buttons

The local control sequence is started by pressing the push-button ∩ (SELECT). After that the LED indicator of the object which has been defined controllable starts flashing.

If the object is closed the indicator for closed position starts flashing and if the object is open the indicator for open position starts flashing. The indicator remains flashing until a control command is given or a timeout of 10 s has elapsed.

The closing or opening command is given by using the I (close) or O (open) push-button. Depending on the status of inputs 1…3 and 4…13 and the interlocking program logic the control module executes the selected command or turns on the INTERLOCK-LED indicating that the operation is interlocked.

The lenght of the the control output pulse can be programmed within the range 0.1…100 s.

Switchgroup SG1

Switch	Function
SG1/1	Switch SG1/1 is used to inhibit interlocking during testing When SG1/1=0, the interlockings are in use When SG1/1=1, the interlockings are not in use and the red TEST- LED is lit. All control operations are allowed. NOTE! This switch position should be used for testing purposes only!
SG1/2	Switch SG1/2 is not in use and should be in position 0.

Display of measured values and serial communication parameters

The displayed items can be stepped through by pressing the STEP push-button. The measured values are indicated by the three green digits at the extreme right. A yellow LED indicator below the STEP push-button shows, when lit, which measured value is indicated on the display.

Indicator	Data to be displayed
I_{L1} [kA]	The measured phase current I_{L1} in actual kiloamperes. The range is 0.000…999 kA, 0.000 is indicated as .000
I_{L2} [kA]	The measured phase current I_{L2} in actual kiloamperes. The range is 0.000…999 kA, 0.000 is indicated as .000
I_{L3} [kA]	The measured phase current I_{L3} in actual kiloamperes. The range is 0.000…999 kA, 0.000 is indicated as .000
P [MW]	The measured active power in megawatts. Both positive and negative values are indicated. The positive values have no sign but the negative sign is indicated by the red digit
Q [MVar]	The measured reactive power in megavars. Both positive and negative values are indicated. The positive values have no sign but the negative sign is indicated by the red digit
E [GWh,MWh,kWh]	The measured active energy. The energy is displayed in three parts; in gigawatthours, in megawatthours and in kilowatthours

Also the serial communication parameters are indicated by the four-digit display. The address of the data to be displayed is indicated by the red digit at the extreme left of the display.

Red digit	Data to be displayed
A	Serial communication address. May have a value within the range 0…254. The default value is 99.
b	Serial communication baudrate. May have values 4.8 or 9.6 kBd. The default value is 9.6 kBd.
C	Serial communication monitor. If the device is connected to a data communicator and the communication system is operating the monitor reading is 0, otherwise the numbers 0…255 are rolling in the display

Continuous display of one measured value or automatic display switch-off after a 5 minutes timeout can be selected.

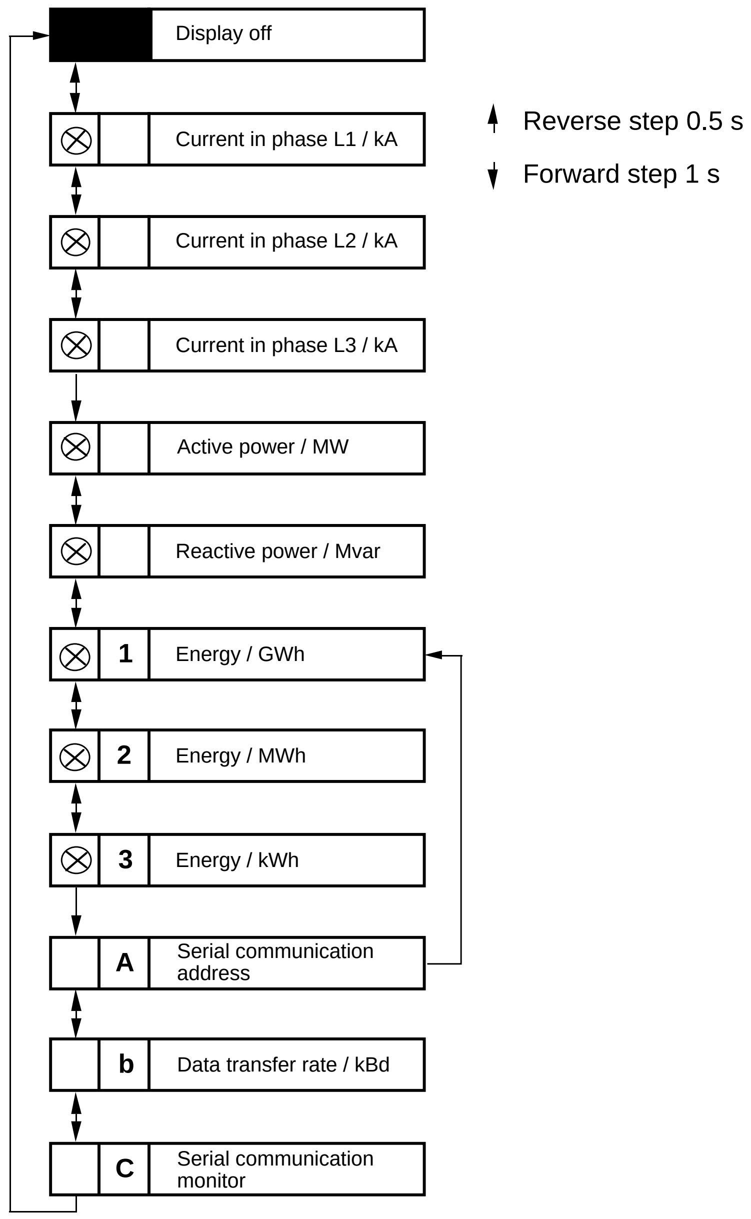


Fig. 5. Display menu of the control module SPTO 1D2.

RS 232 interface

The 9-pin RS 232 interface on the front panel is to be used for programming the control module from a terminal or a PC. The control module SPTO 1D2 supervises the serial communication of the feeder terminal. This enables protection modules of the same terminal to be set via the RS 232 interface.

If a terminal or a PC is connected to the RS 232 interface the SPA-bus interface on the rear panel of the feeder terminal is disconnected. When using the RS 232 interface, the SPA-bus protocol has to be used.

The following serial communication parameters should be used:

- Number of data bits, 7
- Number of stop bits, 1
- Parity, even
- Baudrate, 9.6 kilobauds as a default

The next table shows the signal names and pin numbers of the cable to be used between the RS 232 interface and a programming device.

RS 232 interface of SPTO 1D2		Programming device		
Signal name	Pin number 9-pin male conn.	Pin number 9-pin female conn.	Pin number 25-pin male conn.	Signal name
Data receive	2	3	2	Data transmit
Data transmit	3	2	3	Data receive
Ground	5	5	7	Ground
DSR	6	4	20	DTR

Programming

Configuration

The control module SPTO 1D2 is able to indicate the status of maximum 3 objects (circuit breakers or disconnectors) and to control (open or close) one object.

The control module can be used for different circuit breaker / disconnector / earth-switch configurations within the above mentioned limits. The configuration can be defined freely by using configuration commands explained below or by choosing a suitable default configuration. Each default configuration uses a fixed interlocking scheme.

The default configurations and interlockings are explained in the appendixes 1…3. If the configuration or the interlocking is not suitable for a certain application then both must be programmed by the user.

After factory testing the default configuration and interlocking 1 has been selected for the control module. Another default configuration is chosen by writing the configuration number for variable S100 via the SPA bus.

Normally the control module is in the run mode which means that the interlocking program is executed. When programming a configuration or selecting a new default setting the control module must be in the program mode (S198=0).

Example 1: Selection of the default configuration and interlocking 2 instead of default 1.

```
>99WS198:0:XX
    ;Change into program mode
>99WS100:2:XX
    ;Select the default 2
>99WS198:1:XX
    ;Change into run mode
>99WV151:1:XX
    ;Store the programmed parameters
```

If variable S100 is 0, the configuration is freely programmable. In this case all indicators are initially set out of use. In a freely programmable configuration, only the objects to be used must be programmed.

The three input channels 1…3 can be used to read status data of circuit breakers and disconnectors. The input channel numbers are used when programming the feeder terminal configuration.

The front panel indicators are numbered from 101 to 116. These numbers are used when programming the feeder terminal configuration. The positions and the numbers of the indicators in the matrix are shown in Fig. 6.

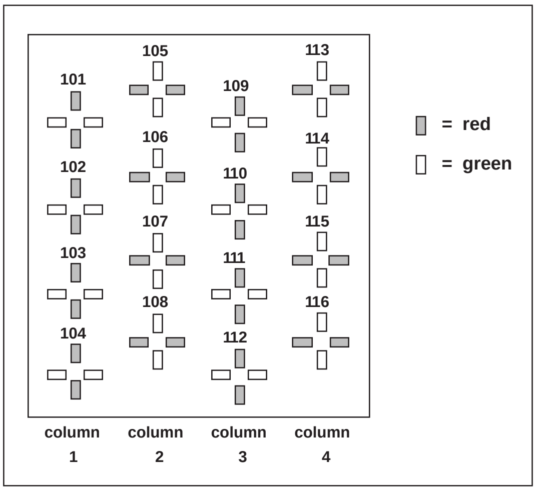


Fig. 6. Position, number and colour of the indicators on the front panel of SPTO 1D2.

The control module has two outputs, OPEN and CLOSE, for controlling one object. The control outputs have their own codes, 20 and 21, which have to be used when programming a configuration. The corresponding operation is given in the following table.

Output code	Operation
20	OPEN
21	CLOSE

For the correspondence between the input and output codes and the rear panel terminal numbers see chapter "Connection diagram" in the user´s manual of the feeder terminal.

When programming a configuration an indicator number, a four-pole input number and an output code are linked together using one SPA protocol command.

The setting parameters S101…S116 which refer to the indicator numbers 101…116 are reserved for the configuration commands. As an output number either the code of OPEN output or CLOSE output can be used. Also some other parameter, such as type of object and position of open and closed status indicators, are defined in the SPA protocol command.

Example 2: Indicator 109 (S109) indicates the status read via input channel 2. Output 20 is used for opening the object which means that output 21 must be used for closing the same object. The object is a circuit breaker and the closed status is indicated by vertical red LEDs.

The command has the formula:

>99 WS 109:1,1,2,20,1:XX

- **1** (last field) — Type of object
  0 = not circuit breaker
  1 = circuit breaker
- **20** — Output code
  0 = object is not controlled
  20 = code of OPEN output
  21 = code of CLOSE output
  Note! Either 20 or 21 can be used if the object is to be controlled.
- **2** — Input channel number
  Channels 1…3
- **1** (second field) — Defines the vertical/horizontal position of open/closed indication
  0 = vertical LEDs indicate open status (horizontal LEDs indicate closed status)
  1 = vertical LEDs indicate closed status (horizontal LEDs indicate open status)
- **1** (first field) — Defines the use of object indicator
  0 = not used
  1 = used
- **109** — Number of object indicator
- **WS** — Write Setting
- **99** — Data communication address
  Default value is 99

Syntax rules for programming the configuration for SPTO 1D2:

1. The programming has to be done in the program mode.
2. Maximum three objects can be configured (three settings in the range of S101…S116).
3. Only input channel numbers 1…3 are accepted. Each number can be used only once.
4. If an object indicator is not used, no other values need to be given.
5. Output code 20 or 21 can be given only once. If the output code is 0, the definition of the object (CB/other object) need not be given.
6. Only one object can be defined to be a circuit breaker.

Example 3: To program a configuration similar to the default configuration 1 (indicator 109 CB truck, indicator 110 CB and indicator 116 earth-switch), the following commands are required:

```
>99WS198:0:XX
    ; Change into program mode
>99WS100:0:XX
    ; Change into freely programmable mode
>99WS109:1,1,1,0:XX
    ; CB truck : vertical red LEDs indicate
      closed status, input channel 1, not
      controlled
>99WS110:1,1,2,20,1:XX
    ; Circuit breaker : vertical red LEDs
      indi cate closed status, input channel 2,
      controlled
>99WS116:1,1,3,0:XX
    ; Earth-switch : horizontal red LEDs
      indicate closed status, input channel 3,
      not controlled
>99WV151:1:XX
    ; Store the programmed parameters
```

After this also the interlocking program must be written before opening or closing of the circuit breaker is possible. See Chapter "Interlocking".

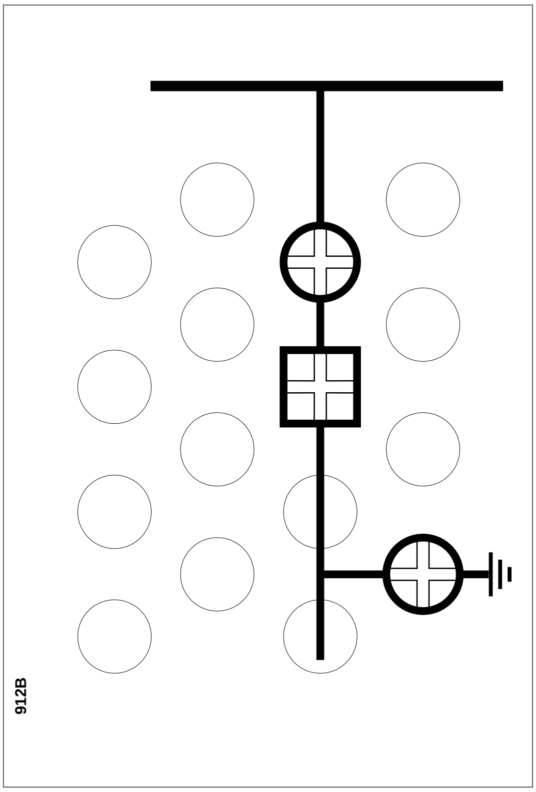


Fig. 7. Configuration programmed in the example number 3.

The programmed configuration can be read indicator by indicator or with a single command.

Example 4: To read the configuration of indicators 101…116 with one command only.

```
>99RS101/116:XX
```

This command will give all the setting values of every indicator (101 to 116), including those not configured into the system. The parameters of indicators not in use are zero.

Interlocking

An interlocking program is used to inhibit the closing or opening command for a controllable object in certain situations. In practice, in the control module SPTO 1D2, the interlocking enables the control operations, i.e. everything that is not enabled by the interlocking program is inhibited.

The default configurations have their own default interlocking programs, see appendixes 1…3. If a default interlocking related to a default configuration is not suitable, both configuration and interlocking must be programmed by the user.

The interlocking system of the control module reads the status of input channels 1…3 and 4…13. The interlocking program enables the opening or closing of a controllable object but a separate open or close command must be given via the local push-buttons, the serial bus or the input channels 4…13.

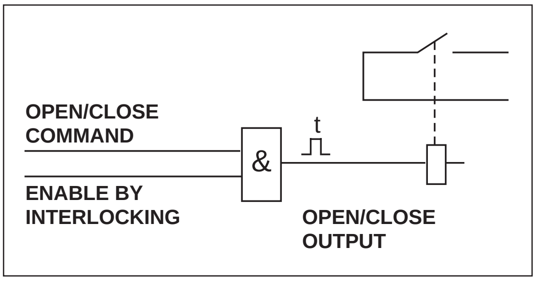


Fig. 8. Operation principle of OPEN and CLOSE outputs.

When the parameter S198 = 0, the module is in the program mode, and when the parameter S198 = 1, the module is in the run mode. In the run mode the interlocking program is executed and it cannot be changed by the operator. The operations enabled by the interlocking program can be carried out.

In the program mode the interlocking program is not executed and program changes can be done. In this mode the control of the objects is not allowed, except in the case that interlockings are completely out of use. The interlocking is programmed or a default interlocking is selected in the program mode.

The interlocking logic, when used, is always operative both in local and remote control mode and if the control commands are given via input channels 4…13. The interlocking program is executed every 20 ms. With setting S199 the interlocking can be taken completely out of use.

Example 5: In example 3 a configuration was programmed. If the interlockings are not used the programming continues with the following commands:

```
>99WS199:0:XX
    ; Disable interlockings
>99WV151:1:XX
    ; Store the programmed parameters
```

In this case when the interlockings are not programmed, the value 1 cannot be given for the parameter S198. However, the status indication and object control operate as normal because the interlockings are disabled.

The interlockings are programmed via the SPA bus using the language according to the DIN 19239 standard. The structure of a program command is:

OPERATION is a logic command
OPERAND is a code of an input or an output or a number of a temporary or a special register

The following logic commands are used:

LOAD	Reads the status of an input or a register
LOADN	Reads the inverted status of an input or a register
AND	And operation
ANDN	And not operation
OR	Or operation
ORN	Or not operation
OUT	Writes to an output or a register
END	End of the program

For inputs 1…3 a separate operand code is defined for each status, open, closed or undefined. The activated status of inputs 4…13 can be used as an operand in the logic.

In SPTO 1D2 the following operand values can be used with operations LOAD, LOADN, AND, ANDN, OR, ORN :

1…3 = input channel number
; Code of an input, if the status " closed" should be used
101…103 = input channel number + 100
; Code of an input, if the status "undefined" should be used
201…203 = input channel number + 200
; Code of an input, if the status "open" should be used
4…13 = input channel number
; Code of an input, if the status "active" should be used
70…89 ; Number of a temporary register
60 and 61 ; Number of a special register
62 ; Position information of the L/R key switch

In SPTO 1D2 the following operand values can be used with operation OUT:

20 or 21 ; Code of an output
70…89 ; Number of a temporary register

The input channel numbers and the output codes are those defined when programming the configuration.

The two special registers, 60 and 61, have constant values; register 60 is always zero (0) and register 61 one (1). Register 62 is used for position information of the L/R key switch; register 62 is one (1) when the L/R key switch is in REMOTE position and zero (0) when the key switch is in LOCAL position. The registers 70...89 are used as temporary data storage during the interlocking program execution.

Example 6: How to store the result of a logic operation into a temporary register.

```
>99WM200:LOAD 201:XX
    ;Read the open status of an object wired
     to the input 1
>99WM201:AND 202:XX
    ;Read the open status of an object wired
     to the input 2
>99WM202:OUT 70:XX
    ;Write the result of the logic operation
     into register 70
```

After these commands register 70 is 1, if both objects are open.

Example 7: How to use input channels 4…13 in the logic.

```
>99WM200:LOAD 1:XX
    ;Read the closed status of an object wired
     to input 1
>99WM201:AND 4:XX
    ;Read the active status of input channel 4
>99WM202:OUT 20:XX
    ;Enable output 20
```

After these commands the OPEN output (code 20) is enabled if object 1 is closed and input channel 4 is activated.

Syntax rules for programming the interlocking for SPTO 1D2:

1. The interlockings have to be programmed in the program mode.
2. With the interlocking program the operator defines when the opening and closing of an object is allowed.
3. The setting parameters M200…M300 are used. A setting parameter is equal to the row number of the interlocking program.
4. The program always begins at M200 and must not include empty lines.
5. The program always begins with the command LOAD or LOADN.
6. The last command of the program must be END.
7. One operand can be used only once with the OUT command.
8. Before the LOAD and LOADN commands, except for the first command, the OUT command should be used.
9. Before the END command an OUT command should be used.

Example 8: Programming of an interlocking logic. This example is related to example 3, the circuit breaker is to be controlled.

The following rules are given for the interlocking:

- Opening of the circuit breaker is always allowed.
- Closing of the circuit breaker is allowed when the CB truck is in the isolating position or in the service position and the earth-switch is open.

Instead of these written interlocking conditions, a logic diagram can be used:

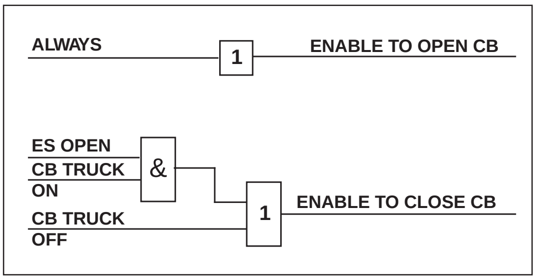


Fig. 9. Simple logic diagram for the interlocking logic for example 8

Below a detailed logic diagram is drawn.

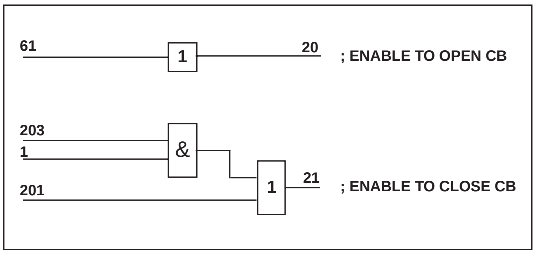


Fig. 10. Detailed logic diagram of the interlocking logic for example 8

The actual commands are written on the basis of the detailed logic diagram. As a default the program area M200…M300 is filled with END commands. The interlocking commands given by the operator are written over these END commands.

A configuration was programmed in example 3. If the interlockings described above are taken into use the programming continues with the following commands.

```
>99WM200:LOAD 61:XX
    ;Read the value of special register 61
     (the value is always 1)
>99WM201:OUT 20:XX
    ;Always enable the open command of
     the CB
>99WM202:LOAD 1:XX
    ;Read the closed status of the CB truck
>99WM203:AND 203:XX
    ;Read the open status of the earth-switch
>99WM204:OR 201:XX
    ;Read the open status of the CB truck
>99WM205:OUT 21:XX
    ;Enable the close command of the CB
>99WM206:END:XX
    ;End of interlocking program

>99WS198:1:XX
    ;Change interlocking program into run
     mode
>99WS199:1:XX
    ;Enable interlockings
>99WV151:1:XX
    ;Store the programmed parameters
```

The program is automatically compiled, when changing back into the run mode. If there are syntax errors in the program, the compiling will not be passed and the interlocking stays in the program mode. First the syntax errors must be corrected and then the interlocking system can be changed into the run mode.

The interlocking program can be by-passed in two ways;

- For testing purposes the switch SG1/1 on the front panel can be turned on. Then the interlocking program is interrupted and opening/closing of an object is always enabled.
- If the interlocking logic is to be taken out of use permanently , then variable S199 can be set to 0. Then the opening or closing of an object is always enabled.

The interlocking system does not affect the tripping signal of the protection.

Conditional Direct Output Control

The Conditional Direct Output Control logic controls the outputs OPEN, CLOSE and SIGNAL1…3. Outputs not used for controlling an object or for signalling the activation of inputs 4…13 can be controlled by the Conditional Direct Output Control function.

The outputs are activated on the basis of the programmed logic and the status of input channels 1…3 and 4…13. The controlled output remains active as long as the statuses of the inputs which caused the operation do not change.

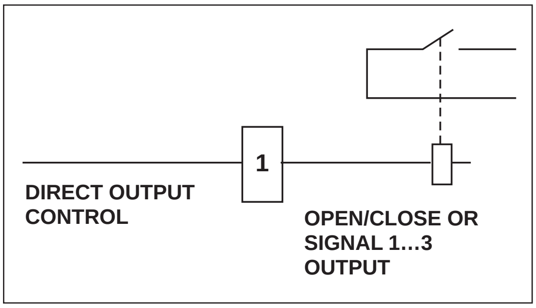


Fig. 11. Operation principle of Conditional Direct Output Control.

The programming principles and the program structure of the Conditional Direct Output Control are the same as those of the interlocking logic. The differences between these two logic programs are;

- The codes of OPEN and CLOSE outputs
- The outputs SIGNAL1…3 can be controlled by the Conditional Direct Output Control program.

The output codes are:

Output code	Definition
220	OPEN
221	CLOSE
22	SIGNAL 1
23	SIGNAL 2
24	SIGNAL 3

The Direct Output Control program is written after the interlocking program by using the SPA protocol commands M200…M300. These two programs have a common END command.

Example 9: An interlocking logic was programmed in example 8. In this example a Conditional Direct Output Control logic is added for SIGNAL 3 output.

The SIGNAL 3 output will be activated when:

- The CB truck is in the isolated position and input channel 4 is activated

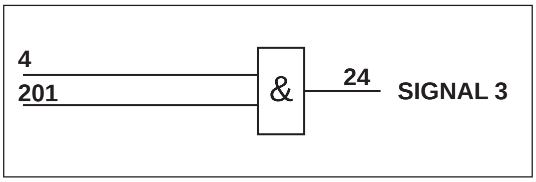


Fig. 12. Detailed logic diagram of the Conditional Direct Output Control logic for the example number 9.

The described Conditional Direct Output Control logic is effectuated with the following commands.

```
…
    ;Interlocking logic command lines
     M200…M205
>99WM206:LOAD 201:XX
    ;Read the open status of the CB truck
>99WM207:AND 4:XX
    ;Read the active status of input 4
>99WM208:OUT 24:XX
    ;Activate the SIGNAL3 output
>99WM209:END:XX
    ;End of program

>99WS198:1:XX
    ;Change the program into run mode
>99WS199:1:XX
    ;Effectuate the program
>99WV151:1:XX
    ;Store the programmed parameters
```

Input channels 4…13

The input channels 4…13 are used to read binary signals other than circuit breaker and disconnector status information. The binary signals can be external contact signals or internal binary signals, e.g. starting and tripping signals of protective relay modules. For the definition of internal and external signals see chapter "Intermodular control signal exchange" in the user´s manual of the feeder terminal.

The status of the binary inputs 4…13 can be read via the serial bus. The status of the input channels 4…9 is also indicated locally by LEDs on the front panel. A LED is lit when the corresponding input becomes active and the LED is switched off when the corresponding input becomes inactive.

Each input channel can be defined to be active at high state or at low state by using parameter S2. The high state activity means that an input is considered to be active if there is a voltage connected to the corresponding external input or if a protective relay module has activated its output signal. Low state activity is the opposite to high state activity. As a default all the inputs are active at high state.

The following features are related to input channels 4…13:

- Events are formed by status changes
- The channels can be used to activate the OPEN or CLOSE output pulse
- The channels can be used to inhibit the OPEN or CLOSE output pulse
- The channels can be used to activate one of the outputs SIGNAL1…3
- The channels may be included in the interlocking program logic
- The channels may be included in the Conditional Direct Output Control logic
- Channel 7 can be used as an energy pulse counter, see chapter "Scaling of measurements".

When using an input channel one signal output (SIGNAL1…3) and one control output (OPEN or CLOSE) can be activated simultaneously. Accordingly one signal output can be activated and one control output inhibited simultaneously. The output to be activated or inhibited is defined by parameters S3 and S4.

The position of the R/L keyswitch is without significance when the control outputs (OPEN or CLOSE) are controlled via inputs 4…13, but a check with the blocking logics is always made before a control action.

If an input channel is defined to control a signal output, the output is activated as long as the input is active. The length of the opening and closing pulse is defined by the SPA bus variables V5 and V6 respectively and they are not depending on the input pulse length.

Example 10: Programming of input 8. The programming can be done in the run mode.

```
>99W8S2:1:XX
    ; Define input 8 to be active at high state
>99W8S3:22:XX
    ; Configure input 8 to activate the SIGNAL1 output
>99W8S4:20:XX
    ; Configure input 8 to activate the OPEN output pulse
>99WV151:1:XX
    ; Store the programmed parameters
```

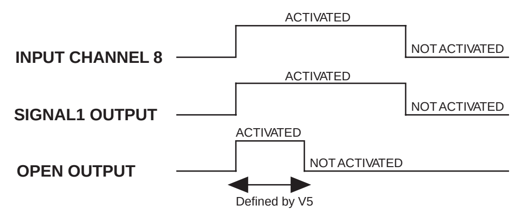


Fig. 13. Operation of outputs SIGNAL1 and OPEN when input channel 8 in example 10 is activated.

If an input channel is used for inhibiting a control command the opening or closing of an object is inhibited as long as the input is active. If the interlockings are out of use (S199=0), the input channels 4…13 cannot be used to inhibit the OPEN and CLOSE outputs.

If the input 7 is operating as an energy pulse counter, it cannot be used for other purposes. As a default the input channels 4…13 are operating in a general input mode, but are not activating or inhibiting any outputs.

Outputs

The control module SPTO 1D2 has five outputs: three signal outputs (SIGNAL1…3) and two control outputs (OPEN and CLOSE). For programming the outputs are coded in the following way:

Output	Output code	Remarks
OPEN	20	For configuration and interlocking
OPEN	220	For Conditional Direct Output Control
CLOSE	21	For configuration and interlocking
CLOSE	221	For Conditional Direct Output Control
SIGNAL1	22	
SIGNAL2	23	
SIGNAL3	24	

The OPEN and CLOSE outputs can be controlled in four ways:

- Locally by using the OPEN and CLOSE push-buttons
- Remotely by commands over the serial bus
- Remotely via the binary inputs 4…13, see chapter "Input channels 4…13"
- By the Conditional Direct Output Control logic, see chapter "Conditional Direct Output Control"

To define the object to be controlled via the outputs OPEN and CLOSE, see chapter "Configuration".

When using the three first ways of operation the OPEN and CLOSE outputs give pulses. Before the output is activated the interlocking logic must enable the operation.

The pulse lengths for opening and closing outputs are defined with the SPA bus variables V5 and V6. The definitions have to be made only for the channel on which the object to be controlled is located. As a default the object to be controlled is located on channel 2.

The pulse lenght can be set in the range 0.1... 100 s with a time resolution of 0.1 s. As a default the values for V5 and V6 of channel 2 are 0.1 s.

Example 11: The pulse lenghts can be programmed in the run mode. In default configuration 1 the object to be controlled is defined to be a CB in channel 2. To change the open and close pulse lengths from 0.1 s the following SPA bus commands are used:

```
>99W2V5:0.5:XX
    ; Set the open pulse length to 0.5 seconds
>99W2V6:0.2:XX
    ; Set the close pulse length to 0.2 seconds
>99WV151:1:XX
    ; Store the programmed parameters
```

The open and close commands are given via the serial communication to the channel on which the object is located. The OPEN and CLOSE outputs can be controlled via the serial communication by using two different procedures:

- Direct control: An output command is given by using the parameter O1. When the parameter has been given the value 0 (open) or 1 (close) the corresponding output pulse is delivered, if enabled by the interlocking.
- Secured control: First an output is set into a state of alert by using parameter V1 for opening and parameter V2 for closing. After that the corresponding output command is executed by using parameter V3. The output pulse is given if the interlocking enables it. The state of alert is cancelled after the execute command. The state of alert can also be cancelled by using parameter V4.

When the Conditional Direct Output Control logic is used for controlling the OPEN and CLOSE output, the output is activated as long as the statuses of the inputs which have caused the operation remain unchanged.

The operation of outputs OPEN and CLOSE can be inhibited in two ways:

- By the interlocking program logic, see chapter "Interlocking"
- By input channels 4…13, see chapter "Input channels 4…13"

The outputs SIGNAL1…3 can be controlled in two ways:

- By input channels 4…13, see chapter "Input channels 4…13"
- By the Conditional Direct Output Control logic, see chapter "Conditional Direct Output Control"

The control module SPTO 1D2 includes a self-supervision system which has its own output, IRF. The output is active when auxiliary power is connected and the self-supervision system has not detected any fault. The output signal goes low if the auxiliary power supply is switched off or a permanent fault is detected. The self-supervision output is connected to the common IRF output of the feeder terminal.

Scaling of measurements

The control module is able to measure three phase currents, active and reactive power and energy. The phase currents are measured via the 1 A or 5 A current inputs of the feeder terminal. For measuring active and reactive power the module includes two mA-inputs. The output signals of external measuring transducers are wired to these two inputs. Energy can be measured in two ways; by using input 7 as a pulse counter or integrating the measured power. If the pulse counter is used an external energy meter with a pulse output is needed.

Phase currents

The three phase currents are displayed locally and transferred in actual kiloamperes via the serial bus. To be able to do this the current measurement must be scaled. The scaling is based on the entered rated current of the primary side of the primary current transformer.

Example 12: Scaling of the phase current measurement.

The nominal current of the primary side of the primary current transformers is 400 A. The current must be given in amperes. The scaling factor is 400.00.

```
>99WS9:400.00:XX
    ;Set scaling factor S9 to 400.00
>99WV151:1:XX
    ;Store the programmed parameters
```

The scaling factor can be programmed within the range 0.00…10000.00. The default value of variable S9 after factory testing is 200.00.

Active and reactive power

The value of the active power is displayed locally and transferred in actual megawatts via the serial bus. Correspondingly the value of the reactive power is displayed locally and transferred in actual megavars via the serial bus. Both negative and positive power values can be measured.

The power measurement is enabled or disabled by means of parameter S91. As a default power measurement is disabled (S91=0). The input signal range of the mA-inputs is -20…20 mA.

The following setting parameters are used for scaling the inputs:

- S12 = Low limit of the mA signal related to active power, sign
- S13 = High limit of the mA signal related to active power, sign
- S14 = Low limit of the mA signal related to reactive power, sign
- S15 = High limit of the mA signal related to reactive power, sign
- S16 = Value of active power corresponding to the mA signal at low limit, sign
- S17 = Value of active power corresponding to the mA signal at high limit, sign
- S18 = Value of reactive power corresponding to the mA signal at low limit, sign
- S19 = Value of reactive power corresponding to the mA signal at high limit, sign

After the power measurement has been enabled the low and high limits of the mA signals are given and then the corresponding values of active and reactive power.

Example 13: The scale of the measured active power ranges from -50 to 135 MW and the corresponding mA range is -20…20 mA.

```
>99WS91:1:XX
    ; Enable power measurement
>99WS12:-20:XX
    ; Set low limit of the mA signal
>99WS13:+20:XX
    ; Set high limit of the mA signal
>99WS16:-50.00:XX
    ; Set value of power corresponding to
     the mA signal -20 mA
>99WS17:+135.00:XX
    ; Set value of power corresponding to
     the mA signal 20 mA
>WV151:1:XX
    ; Store the programmed parameters
```

Example 14: The scale of the measured reactive power ranges from 0 to 2.2 Mvar and the corresponding mA range is 4...20 mA.

```
>99WS91:1:XX
    ; Enable power measurement
>99WS14:+4:XX
    ; Set the low limit of the mA signal
>99WS15:+20:XX
    ; Set the high limit of the mA signal
>99WS18:+0.00:XX
    ; Set the value of power corresponding
     to the mA signal 4 mA
>99WS19:+2.20:XX
    ; Set the value of the power corresponding
     to the mA-signal 20 mA
>99WV151:1:XX
    ; Store the programmed parameters
```

The scaled active and reactive power can be transmitted to the remote control system as SPA-bus variables V3 and V4 for the active power and reactive power respectively.

Energy

Input channel 7 can be used for counting energy pulses. The measured energy is displayed locally by three digits in three parts; in kilowatthours, in megawatthours and in gigawatthours. Correspondingly, the energy value can be read via the serial bus in three parts with maximum three digits (parameters V8…V10) but also in one part in kilowatthours with maximum nine digits (parameter V5). Before the pulse counter can be used the energy measurement must be enabled by variable S92. As a default energy is not measured (S92=0).

The following parameters must be defined for channel 7:

S1 = definition of channel 7
- 0 = general ON/OFF input (default)
- 1 = pulse counter without local indication with front panel LED
- 2 = pulse counter with local indication with front panel LED

S2 = pulse direction
- 0 = negative pulse
- 1 = positive pulse (default)

The following parameters must be defined for channel 0:

S3 = definition of kWh value per pulse, range 0.01…1000 kWh per pulse. Default value is 1.

Example 15: Measurement of energy via the pulse counter.

```
>99WS92:1:XX
    ; Enable energy measurement
>99WS3:5:XX
    ; Set energy value 5 kWh per pulse
>99W7S1:1:XX
    ; Set input 7 as a pulse counter without
     local indication
>99W7S2:1:XX
    ; Set a positive polarity of pulses
>99WV151:1:XX
    ; Store the programmed parameters
```

The energy can also be integrated by using the measured active and reactive power. In this case the measured active energy in one direction is displayed locally whereas the measured active and reactive energy can be read in both directions via the serial bus.

The integration is used automatically if the energy measurement is enabled by parameter S92 but input channel 7 is not defined as a pulse counter.

Example 16: Measurement of energy by integrating the measured power. Initially the measurement of power must be enabled and scaled, see examples 13 and 14.

```
>99WS92:1:XX
    ; Enable energy measurement
>99WV151:1:XX
    ; Store the programmed parameters
```

Event codes

Over the SPA bus substation level data communicator can read the event data, change in status, produced by the control module SPTO 1D2. The events are represented by the event codes e.g. E1…E11. The control module transmits its event data in the format:

<time> <channel number><event code>

where time = ss.sss (seconds and parts of second)
channel number = 0...13
event code = E1...E54, depending on the channel

Most of the event codes and the events represented by these may be included in or excluded from the event reporting by writing an event mask (V155) to the module. The event mask is a binary number coded to a decimal number. Each channel (0...13) has its own event mask.

Each event code is represented by a number. An event mask is formed by multiplying the number either by 1, which means that event is included in the reporting, or by 0, which means that event is not included in the reporting, and finally adding up the results of multiplications.

Example 17: Calculation of the event mask.

Channel	Event code	Event	Number representing the event	Event factor	Result of multiplication
2	E1	Change in status: xx ->10 (open)	1	x 1	= 1
2	E2	Change in status: xx ->01 (close)	2	x 1	= 2
2	E3	Change in status: xx ->11 (undefined)	4	x 0	= 0
2	E4	Change in status: xx ->00 (undefined)	8	x 1	= 8
2	E5	OPEN output activated	16	x 1	= 16
2	E6	OPEN output reset	32	x 0	= 0
2	E7	CLOSE output activated	64	x 1	= 64
2	E8	CLOSE output reset	128	x 0	= 0
2	E9	Output activation inhibited	256	x 1	= 256
2	E10	Output activation fault	512	x 0	= 0
2	E11	Attempt to activate an output without open/close selection	1024	x 0	= 0
Event mask V155 for channel 2					347

The event mask V155 of channel 0 and channels 4…13 may have a value within the range 0…15 and the event mask of channels 1…3 within the range 0…2047. The default values are shown in the next table.

Channels 1...13 have a setting S20, which enables or inhibits the event reporting of the corresponding channel. The default value is 0, which means that event reporting is allowed according to event mask.

The settings S10...S13 for channels 1...3 and settings S10 and S11 for channels 4…13 define the event delays. The event delays are used for filtering out unwanted events when status data is changing. An event code is generated only if the status data is stable for a longer time than the corresponding delay time, e.g. the event code E4 "change in status: xx -> 00" can be filtered out when the status of an object is changing from open to close and vice versa. The time marking of a delayed event is the actual event time added with the delay time.

The control module has the following event codes:

Channel	Code	Event	Number representing event	Default value of event factor
0	E1	Key switch to LOCAL position	1	1
0	E2	Key switch to REMOTE position	2	1
0	E3	Output test switch SG1/1 ON	4	0
0	E4	Output test switch SG1/1 OFF	8	0

V155 = 3

Channel	Code	Event	Number representing event	Default value of event factor
1…3	E1	Change in status; xx -> 10 (open)	1	1
1…3	E2	Change in status; xx -> 01 (closed)	2	1
1…3	E3	Change in status; xx ->11 (undefined)	4	0
1…3	E4	Change in status; xx ->00 (undefined)	8	0
1…3	E5	OPEN output activated	16	1
1…3	E6	OPEN output reset	32	0
1…3	E7	CLOSE output activated	64	1
1…3	E8	CLOSE output reset	128	0
1…3	E9	Output activation inhibited 1)	256	1
1…3	E10	Output activation fault 2)	512	1
1…3	E11	Trying to activate an output without open/close selection 3)	1024	1

V155 = 1875

Channel	Code	Event	Number representing event	Default value of event factor
4…13	E1	Input channel activated	1	1
4…13	E2	Input channel reset	2	1
4…13	E3	SIGNAL1…3 output activated	4	0
4…13	E4	SIGNAL1…3 output reset	8	0

V155 =3

Channel	Code	Event	Number representing event	Default value of event factor
0	E50	Restarting	*	-
0	E51	Overflow of event register	*	-
0	E52	Temporary disturbance in data communication	-	
0	E53	No response from the module over the data communication	*	-
0	E54	The module responds again over the data communication	*	-

0 not included in the event reporting
1 included in the event reporting
* no code number
\- cannot be programmed

In the SPACOM system the event codes E52…E54 are formed by the station level control data communicator.

1) Event E9, output activation inhibited, is given when the operation is inhibited by the interlocking program or by an input channel 4…13.

2) Event E10, output activation fault, is given if the status of the controlled object does not change during the time of the output pulse.

3) Event E11, attempt to activate an output without an open/close selection, is given when a secured control is made in a situation where the state of alert has not been defined.

Programming quick reference

If all the parameters are programmed at the same time the following instructions should be used when changing between program and run mode and when storing the parameters.

As a default the parameters related to interlocking and configuration have the following values:

S100 = 1
    Default configuration and interlocking 1
S198 = 1
    The interlocking program is in run mode
S199 = 1
    Interlockings are in use

The following examples illustrate the programming.

Example 18: Select another configuration and interlocking than default 1.

```
>99WS198:0:XX
    ;Change into program mode
>99WS100:2:XX
    ;Select the default 2
>99WS198:1:XX
    ;Change into run mode
.
    ;Change other parameters
.
.
>99WV151:1:XX
    ;Store the programmed parameters
```

Example 19: Select a user defined configuration and interlocking.

```
>99WS198:0:XX
    ;Change into program mode
>99WS100:0:XX
    ;Change into freely programmable mode
>99WS101:…
    ;Configuration commands
.
.
.
>99WM200:…
    ;Interlocking program
.
.
.
>99WS198:1:XX
    ;Change into run mode
.
    ;Change other parameters
.
.
>99WV151:1:XX
    ;Store the programmed parameters
```

Serial communication parameters

Apart from the event codes the substation level data communicator is able to read, over the SPA-bus, all input data (I-data) of the module, setting values (S-data), information recorded in the memory (V-data), and some other data. Further, part of the data can be altered by commands given over the SPA-bus.

Data	Channel	Code	Data direction	Values
Current in phase L1 (x I_n)	0	I1	R	0.00…2.50 x I_n
Current in phase L2 (x I_n)	0	I2	R	0.00…2.50 x I_n
Current in phase L3 (x I_n)	0	I3	R	0.00…2.50 x I_n
Active power (bits)	0	I4	R	-1023…1023 bits
Reactive power (bits)	0	I5	R	-1023…1023 bits
Current in phase L1 (A)	0	I6	R	0…9999 A
Current in phase L2 (A)	0	I7	R	0…9999 A
Current in phase L3 (A)	0	I8	R	0…9999 A
Status of an object	1…3	I1	R	0 = undefined (inputs 00) 1 = closed 2 = open 3 = undefined (inputs 11)
Closed status of an object	1…3	I2	R	0 = not closed 1 = closed
Open status of an object	1…3	I3	R	0 = not open 1 = open
Status of inputs 4…13	4…13	I1	R	0 = not active 1 = active
Direct output write	1…3	O1	W	0 = open 1 = close
Open select (secured operation)	1…3	V1	RW	0 = non select 1 = select
Close select (secured operation)	1…3	V2	RW	0 = non select 1 = select
Execute selected open/close operation	1…3	V3	W	1 = execute selected operation
Cancel selected open/close operation	1…3	V4	W	1 = cancel selected operation
Open pulse length	1…3	V5	RW(e)	0.1…100.0 s
Close pulse length	1…3	V6	RW(e)	0.1…100.0 s
Execute selected open/close operation (common addr. 900)	0	V251	W	1 = execute all selected operations
Cancel selected open/close operations (common addr. 900)	0	V252	W	1 = cancel all selected operations
kWh value per pulse	0	S3	RW(e)	0.01…1000 kWh per pulse
Position of switch SG1/1	0	S6	R	0 = operation position (SG1/1=0) 1 = interlockings off (SG1/1=1)
Object indication mode	0	S7	RW(e)	0 = continuous display 1 = automatic switch-off after 10 min.
Display indication mode	0	S8	RW(e)	0 = continuous display 1 = automatic switch-off after 5 min.

Data	Channel	Code	Data direction	Values
Scaling of current measurement	0	S9	RW(e)	0.00…10000.00
Low limit for mA signal of active power	0	S12	RW(e)	-20…+20 mA
High limit for mA signal of active power	0	S13	RW(e)	-20…+20 mA
Low limit for mA signal of react. power	0	S14	RW(e)	-20…+20 mA
High limit for mA signal of react. power	0	S15	RW(e)	-20…+20 mA
Active power corresponding to the mA signal at low limit	0	S16	RW(e)	- 999.99…+999.99
Active power corresponding to the mA signal at high limit	0	S17	RW(e)	- 999.99…+999.99
Reactive power corresponding to the mA signal at low limit	0	S18	RW(e)	- 999.99…+999.99
Reactive power corresponding to the mA signal at high limit	0	S19	RW(e)	- 999.99…+999.99
Power measurement	0	S91	RW(e)	0 = no power measurement 1 = power is measured
Energy measurement	0	S92	RW(e)	0 = no energy measurement 1 = energy is measured
Configuration and interlocking	0	S100	RW(e)	0 = freely programmable configuration and interlocking program 1 = default 1 2 = default 2 10 = default 10
Configuration of objects (format; value 1, value 2, input No, output No, value 3)	0	S101 : S116	RW(e)	- value 1; 0 = indicator not used 1 = indicator used - value 2; 0 = vertical LEDs indicate open status 1 = vertical LEDs indicate closed status - input number; 1…3 = input number 1…3 - output number; 0 = not controlled object 20 or 21 = outputs 20 and 21 used - value 3; 0 =object other than a CB 1 = object is a CB
Program/run mode selection	0	S198	RW(e)	0 = program mode 1 = run mode
Interlocking selection	0	S199	RW(e)	0 = no interlockings 1 = interlockings in use 2 = for future use

Data	Channel	Code	Data direction	Values
Interlocking and Conditional Direct Output Control program (format; operation, operand)	0	M200 : M300	RW(e)	operation = LOAD, LOADN AND, ANDN OR, ORN OUT END operands for interlocking = status closed (1…3) or active (4…13) status undefined (101…103) status open (201…203) No. of output (20 or 21) No. of memory (70…89) operands for Conditional Direct Output Control = status closed (1…3) or active (4…13) status undefined (101…103) status open (201…203) No of output (22…24, 220 or 221) No of memory (70…89)
Event delay; —>10 (open)	1…3	S10	RW(e)	0.0, or 0.1…60.0 s
Event delay; —>01 (close)	1…3	S11	RW(e)	0.0, or 0.1…60.0 s
Event delay; —>11 (undefined)	1…3	S12	RW(e)	0.0, or 0.1…60.0 s
Event delay; —>00 (undefined)	1…3	S13	RW(e)	0.0, or 0.1…60.0 s
Use of input 7	7	S1	RW(e)	0 = general mode 1 = pulse counter without indication 2 = pulse counter with indication
Operation direction of inputs 4…13	4…13	S2	RW(e)	0 = active at low state 1 = active at high state
Signal output activation by inputs 4…13	4…13	S3	RW(e)	0 = no SIGNAL output 22 = SIGNAL1 output is activated 23 = SIGNAL2 output is activated 24 = SIGNAL3 output is activated
Operation of OPEN and CLOSE outputs by inputs 4…13	4…13	S4	RW(e)	0 = no activation or inhibit 20 = activate OPEN output 21 = activate CLOSE output 120 = inhibit OPEN output 121 = inhibit CLOSE output

Data	Channel	Code	Data direction	Values
Memory controlled function of the indicators of the binary inputs	4…9	S5	RW(e)	0 = not memory controlled 1 = memory controlled
Event delay; —>activated	4…13	S10	RW(e)	0.0, or 0.1…60.0 s
Event delay; —>reset	4…13	S11	RW(e)	0.0, or 0.1…60.0 s
Event reporting	1…13	S20	RW(e)	0 = event reporting enabled 1 = event reporting inhibited
Active power (MW)	0	V3	R	-999.99…+999.99 MW
Reactive power (Mvar)	0	V4	R	-999.99…+999.99 Mvar
Active energy (kWh)	0	V5	RW	0…999999999 kWh
Status of the local/remote key switch	0	V6	R	0 = local 1 = remote
Active energy (kWh)	0	V8	RW	0…999 kWh
Active energy (MWh)	0	V9	RW	0…999 MWh
Active energy (GWh)	0	V10	RW	0…999 GWh
Active energy; reversed (kWh)	0	V11	RW	0…999 kWh
Active energy; reversed (MWh)	0	V12	RW	0…999 MWh
Active energy; reversed (GWh)	0	V13	RW	0…999 GWh
Reactive energy (kvarh)	0	V14	RW	0…999 kvarh
Reactive energy (Mvarh)	0	V15	RW	0…999 Mvarh
Reactive energy (Gvarh)	0	V16	RW	0…999 Gvarh
Reactive energy; reversed (kvarh)	0	V17	RW	0…999 kvarh
Reactive energy; reversed (Mvarh)	0	V18	RW	0…999 Mvarh
Reactive energy; reversed (Gvarh)	0	V19	RW	0…999 Gvarh
Data store into EEPROM	0	V151	W	1 = store, takes about 5 s
Load default values after EEPROM failure	0	V152	RW(e)	0 = enable to load default values 1 = inhibit to load default values
Event mask	0	V155	RW(e)	0…15
Event mask	1…3	V155	RW(e)	0…2047
Event mask	4…13	V155	RW(e)	0…15
Activation of self-supervision output	0	V165	W	0 = reset 1 = activate
Internal fault code	0	V169	R	Fault code
Data communication address	0	V200	RW(e)	1…255
Data transfer rate	0	V201	RW(e)	4800, 9600
Program version symbol	0	V205	R	E.g. 054 A

Data	Channel	Code	Data direction	Values
Type designation of the module	0	F	R	SPTO 1D2
Reading of event register	0	L	R	Time, channel number and event code
Re-reading of event register	0	B	R	Time, channel number and event code
Reading of module status information	0	C	R	0 = normal state 1 = module been subject to automatic reset 2 = overflow of event register 3 = events 1 and 2 together
Resetting of module status information	0	C	W	0 = resetting
Time reading and setting	0	T	RW	0.000…59.999 s

R = Data which can be read from the unit
W = Data which can be written to the unit
(e) = Data which has to be stored into EEPROM (V151) after having been changed

The data transfer codes L, B, C and T have been reserved for the event data transfer between the module and the station level data communicator.

The event register can be read by the L command only once. Should a fault occur e.g. in the data transmission, it is possible, by using the B command, to re-read the contents of the event register once read by means of the L command. When required, the B command can be repeated.

Default values of the parameters

The parameters stored in the EEPROM have been given default values after factory testing. All the default values have been stored in the EEPROM by pressing the push-buttons STEP and SELECT at the same time as the auxiliary power supply was connected. The push-buttons have to be pressed until the display is lit.

The following table gives the default values of the parameters.

Parameter	Channel	Code	Default value
Open pulse lenght	2	V5	0.1 s
Close pulse lenght	2	V6	0.1 s
kWh value per pulse	0	S3	1 kWh per pulse
Object indication mode	0	S7	0 = continuous display
Display indication mode	0	S8	0 = continuous display
Scaling of current measurement	0	S9	200.00
Low limit of mA-signal of active power	0	S12	+4 mA
High limit of mA-signal of active power	0	S13	+20 mA
Low limit of mA-signal of react. power	0	S14	+4 mA
High limit of mA-signal of react. power	0	S15	+20 mA
Active power corresponding to the mA-signal at low limit	0	S16	+0.00
Active power corresponding to the mA-signal at high limit	0	S17	+999.99
Reactive power corresponding to the mA-signal at low limit	0	S18	+0.00
Reactive power corresponding to the mA-signal at low limit	0	S19	+999.99
Power measurement	0	S91	0 = no power measurement
Energy measurement	0	S92	0 = no energy measurement
Configuration and interlocking	0	S100	1 = default configuration and interlocking 1
Configuration of objects	0	S101 : S116	default configuration 1, see appendix 1
Program/run mode selection	0	S198	1 = run mode
Interlocking selection	0	S199	1 = interlockings in use
Interlocking program	0	M200 : M300	default interlocking 1, see appendix 1
Event delay; —>10 (open)	1…3	S10	0.0 s
Event delay; —>01 (close)	1…3	S11	0.0 s
Event delay; —>00, —>11	1 and 3	S12	10.0 s
Event delay; —>00, —>11	2	S12	0.2 s
Use of input 7	7	S1	0 = general mode
Operation direction of intputs 4…13	4…13	S2	1 = active at high state
Signal output activation by inputs 4…13	4…13	S3	0 = no signal output
Operation of OPEN and CLOSE outputs by inputs 4…13	4…13	S4	0 = no activation or inhibit
Memory controlled function of the indicators of the binary inputs	4…9	S5	0 = not memory controlled

Parameter	Channel	Code	Default value
Event delay; —>activated	4…13	S10	0.0 s
Event delay; —>reset	4…13	S11	0.0 s
Event reporting	1…13	S20	0 = event reporting enabled
Load default values after EEPROM failure	0	V152	1 = inhibited
Event mask	0	V155	3
Event mask	1…3	V155	1875
Event mask	4…13	V155	3
Data communication address	0	V200	99
Data transfer rate	0	V201	9600

Technical data

Control functions

- status indication for maximum 3 objects, e.g. circuit breakers, disconnectors, earth switches
- configuration freely programmable by the user
- remote or local control (open and close) for one object
- output pulse length programmable, 0.1…100.0 s
- 10 other binary inputs to read contact data other than status information
- feeder oriented interlocking freely programmable, the 3 status inputs and 10 other binary inputs may be included
- the 10 binary inputs may be used to operate the OPEN and CLOSE outputs
- three signal outputs, can be controlled by the 10 binary inputs

Measurements

- measurement of three phase currents
- phase current measuring range 0…2.5 x I_n
- phase current measuring accuracy better than ±1 % of I_n
- two mA inputs for measuring active and reactive power
- mA input range -20…20 mA, can be limited by programming
- power measuring accuracy better than ±1 % of maximum value of measuring range
- one pulse counter input for energy pulse counting, maximum frequency 25 Hz
- energy can also be calculated on the basis of measured power
- all measured values can be scaled to actual primary values
- local display or remote reading of measured values

Appendix 1

Default configuration and interlocking 1

Default configuration and interlocking 1 is selected by giving variable S100 the value 1. The other parameters have the values given in the chapter "Default values of the parameters"

Configuration

The configuration has three objects, a circuit breaker, a circuit breaker truck and an earth-switch. The close state is indicated with red colour and the open state with green colour. The following inputs, indicators and outputs are used:

- Circuit breaker;
  input channel 2, indicator 110, controlled by OPEN (20) and CLOSE (21) output
- Circuit breaker truck;
  input channel 1, indicator 109, not controlled
- Earth-switch;
  input channel 3, indicator 116, not controlled

The configuration commands are:

S109:1,1,1,0,0
S110:1,1,2,20,1
S116:1,0,3,0,0

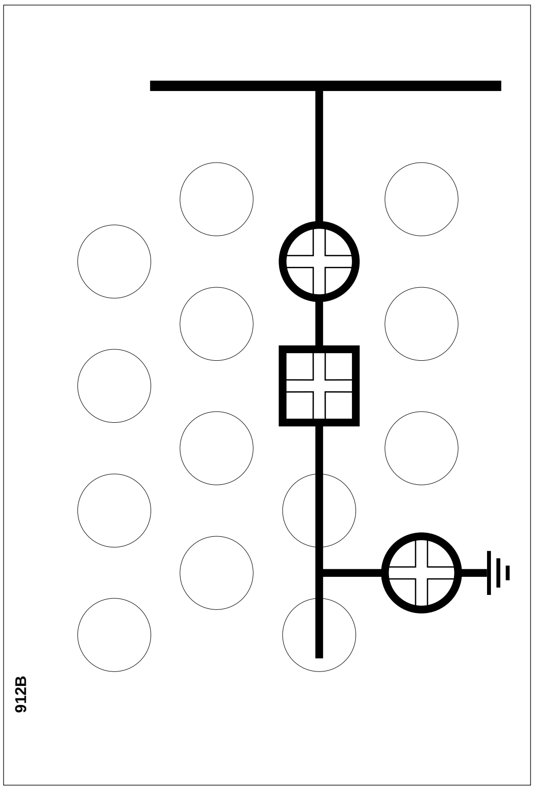


Fig. 14. Default configuration 1.

Interlocking

The following rules apply for interlocking:

- The CB can always be opened.
- The CB can be closed if the CB truck is in the isolated position or if the CB truck is in the service position and the earth-switch is open.

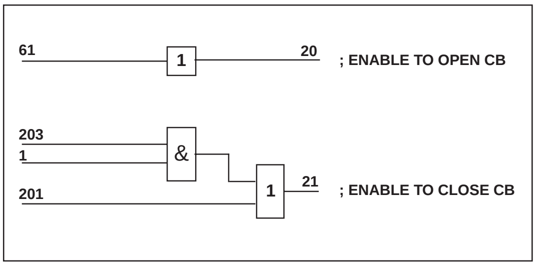


Fig. 15. Logic diagram for the default interlocking 1.

The interlocking program has the following formula:

M200:LOAD 61
M201:OUT 20
M202:LOAD 1
M203:AND 203
M204:OR 201
M205:OUT 21
M206:END

Appendix 2

Default configuration and interlocking 2

Default configuration and interlocking 2 is selected by giving variable S100 the value 2. The other parameters have the values given in the chapter "Default values of the parameters"

Configuration

The configuration has three objects, a circuit breaker, a circuit breaker truck and an earth-switch. The close state is indicated with red colour and the open state with green colour. The following inputs, indicators and outputs are used:

- Circuit breaker;
  input channel 2, indicator 110, controlled by OPEN (20) and CLOSE (21) output
- Circuit breaker truck;
  input channel 1, indicator 109, not controlled
- Earth-switch;
  input channel 3, indicator 116, not controlled

The configuration commands are:

S109:1,1,1,0,0
S110:1,1,2,20,1
S116:1,0,3,0,0

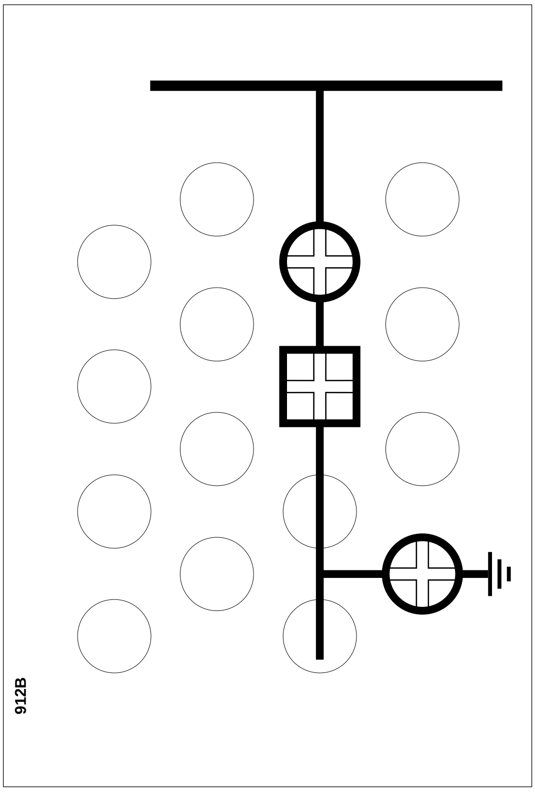


Fig. 16. Default configuration 2.

Interlocking

The following rules apply for interlocking:

- The CB can always be opened.
- The CB can be closed if the CB truck is in service position, the CB is open and the earth-switch is open.

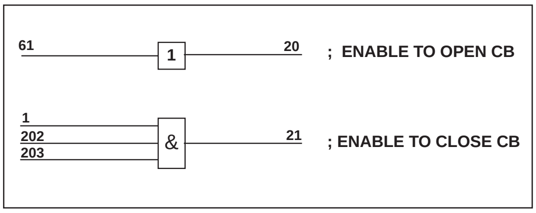


Fig. 17. Logic diagram for the default interlocking 2.

The interlocking program has the following formula:

M200:LOAD 61
M201:OUT 20
M202:LOAD 1
M203:AND 202
M204:AND 203
M205:OUT 21
M206:END

Default configuration and interlocking 10

Default configuration and interlocking 10 is selected by giving variable S100 the value 10. The other parameters have the values given in the chapter "Default values of the parameters".

Configuration

The configuration has three objects, a circuit breaker, a circuit breaker truck and an earth-switch. The close state is indicated with green colour and the open state with red colour. This default is the same as default 1, but the colours of the object indicators are reversed. The following inputs, indicators and outputs are used:

- Circuit breaker;
  input channel 2, indicator 107, controlled by OPEN (20) and CLOSE (21) output
- Circuit breaker truck;
  input channel 1, indicator 106, not controlled
- Earth-switch;
  input channel 3, indicator 104, not controlled

The configuration commands are:

S106:1,1,1,0,0
S107:1,1,2,20,1
S104:1,0,3,0,0

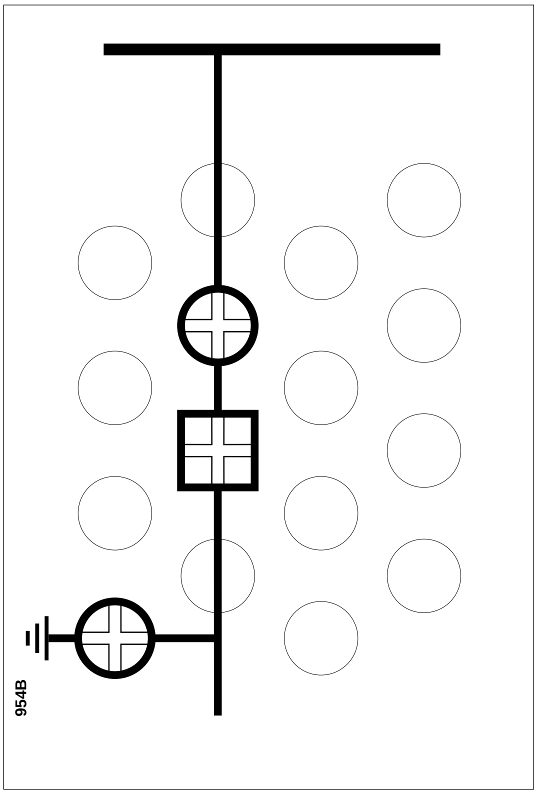


Fig. 18. Default configuration 10.

Interlocking

The interlocking is defined with the following rules:

- The CB can always be opened.
- The CB can be closed if the CB truck is in the isolated position or if the CB truck is in the service position and the earth-switch is open.

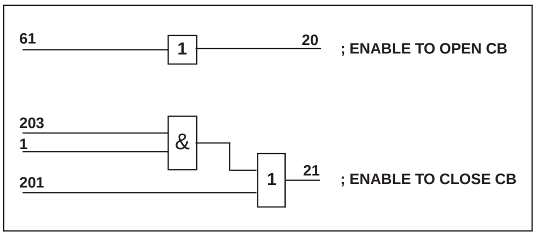


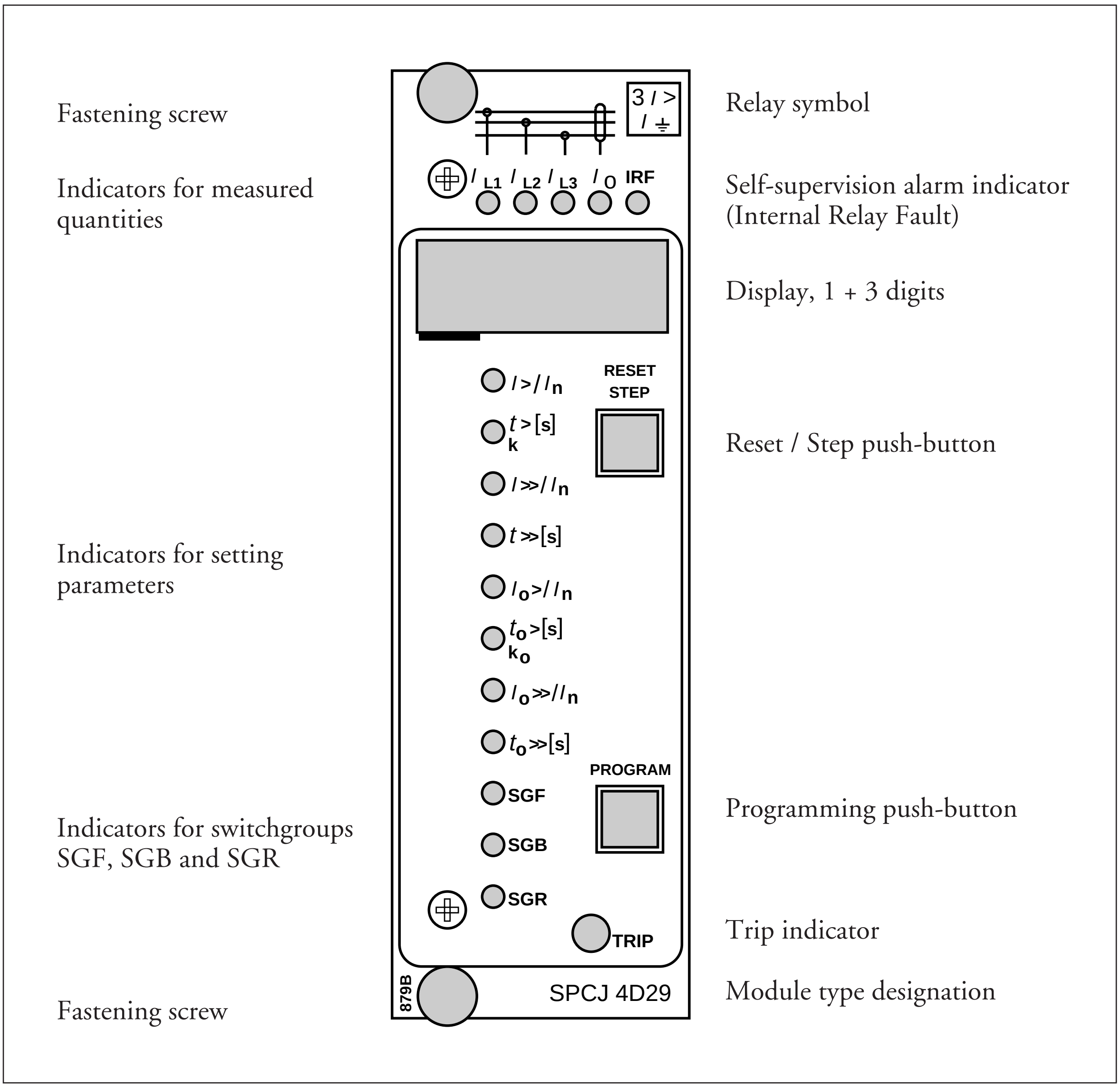
Fig. 19. Logic diagram for the default interlocking 10.

The interlocking program has the following formula:

M200:LOAD 61
M201:OUT 20
M202:LOAD 1
M203:AND 203
M204:OR 201
M205:OUT 21
M206:END

General characteristics of D-type relay modules

User´s manual and Technical description



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General characteristics of D type relay modules

Contents

Control push-buttons

The front panel of the relay module contains two push buttons. The RESET / STEP push button is used for resetting operation indicators and for stepping forward or backward in the display main menu or submenus. The PROGRAM push button is used for moving from a certain position in the main menu to the corresponding submenu, for entering the setting mode of a certain parameter and together with the STEP push button for storing the set values. The different operations are described in the subsequent paragraphs in this manual.

Display

The measured and set values and the recorded data are shown on the display of the protection relay module. The display consists of four digits. The three green digits to the right show the measured, set or recorded value and the leftmost red digit shows the code number of the register. The measured or set value displayed is indicated by the adjacent yellow LED indicator on the front panel. When a recorded fault value is being displayed the red digit shows the number of the corresponding register. When the display functions as an operation indicator the red digit alone is shown.

When the auxiliary voltage of a protection relay module is switched on the module initially tests the display by stepping through all the segments of the display for about 15 seconds. At first the corresponding segments of all digits are lit one by one clockwise, including the decimal points. Then the center segment of each digit is lit one by one. The complete sequence is carried out twice. When the test is finished the display turns dark. The testing can be interrupted by pressing the STEP push button. The protection functions of the relay module are alerted throughout the testing.

Display main menu

Any data required during normal operation are accessible in the main menu i.e. present measured values, present setting values and recorded parameter values.

The data to be shown in the main menu are sequentially called up for display by means of the STEP push button. When the STEP push button is pressed for about one second, the display moves forward in the display sequence. When the push button is pressed for about 0.5 seconds, the display moves backward in the display sequence.

From a dark display only forward movement is possible. When the STEP push button is pushed constantly, the display continuously moves forward stopping for a while in the dark position.

Unless the display is switched off by stepping to the dark point, it remains lit for about 5 minutes from the moment the STEP push button was last pushed. After the 5 minutes' time-out the dispaly is switched off.

Display submenus

Less important values and values not very often set are displayed in the submenus. The number of submenus varies with different relay module types. The submenus are presented in the description of the concerned protection relay module.

A submenu is entered from the main menu by pressing the PROGRAM push button for about one second. When the push button is released, the red digit of the display starts flashing, indicating that a submenu has been entered. Going from one submenu to another or back to the main menu follows the same principle as when moving from the main menu display to another; the display moves forward when the STEP push button is pushed for one second and backward when it is pushed for 0.5 seconds. The main menu has been re-entered when the red display turns dark.

When a submenu is entered from a main menu of a measured or set value indicated by a LED indicator, the indicator remains lit and the address window of the display starts flashing. A submenu position is indicated by a flashing red address number alone on the dispaly without any lit set value LED indicator on the front panel.

Selector switch-groups SGF, SGB and SGR

Part of the settings and the selections of the operation characteristic of the relay modules in various applications are made with the selector switchgroups SG_ . The switchgroups are software based and thus not physically to be found in the hardware of the relay module. The indicator of the switchgroup is lit when the checksum of the switchgroup is shown on the display. Starting from the displayed checksum and by entering the setting mode, the switches can be set one by one as if they were real physical switches. At the end of the setting procedure, a checksum for the whole switchgroup is shown. The checksum can be used for verifying that the switches have been properly set. Fig. 2 shows an example of a manual checksum calculation.

When the checksum calculated according to the example equals the checksum indicated on the display of the relay module, the switches in the concerned switchgroup are properly set.

Switch No	Pos.		Weigth		Value
1	1	x	1	=	1
2	0	x	2	=	0
3	1	x	4	=	4
4	1	x	8	=	8
5	1	x	16	=	16
6	0	x	32	=	0
7	1	x	64	=	64
8	0	x	128	=	0
	Checksum		Σ	=	93

Fig. 2. Example of calculating the checksum of a selector switchgroup SG_.

The functions of the selector switches of the different protection relay modules are described in detail in the manuals of the different relay modules.

Settings

Most of the start values and operate times are set by means of the display and the push buttons on the front panel of the relay modules. Each setting has its related indicator which is lit when the concerned setting value is shown on the display.

In addition to the main stack of setting values most D type relay modules allow a second stack of settings. Switching between the main settings and the second settings can be done in three different ways:

1) By command V150 over the serial communication bus
2) By an external control signal BS1, BS2 or RRES (BS3)
3) Via the push-buttons of the relay module, see submenu 4 of register A.

Setting mode

Generally, when a large number of settings is to be altered, e.g. during commissioning of relay systems, it is recommended that the relay settings are entered with the keyboard of a personal computer provided with the necessary software. When no computer nor software is available or when only a few setting values need to be altered the procedure described below is used.

The registers of the main menu and the submenus contain all parameters that can be set. The settings are made in the so called setting mode, which is accessible from the main menu or a submenu by pressing the PROGRAM push button, until the whole display starts flashing. This position indicates the value of the parameter before it has been altered. By pressing the PROGRAM push button the programming sequence moves forward one step. First the rightmost digit starts flashing while the rest of the display is steady. The flashing digit is set by means of the STEP push button. The flashing cursor is moved on from digit to digit by pressing the PROGRAM push button and in each stop the setting is performed with the STEP push button. After the parameter values have been set, the decimal point is put in place. At the end the position with the whole display flashing is reached again and the data is ready to be stored.

A set value is recorded in the memory by pressing the push buttons STEP and PROGRAM simultaneously. Until the new value has been recorded a return from the setting mode will have no effect on the setting and the former value will still be valid. Furthermore *any attempt to make a setting outside the permitted limits for a particular parameter will cause the new value to be disqualified and the former value will be maintained.* Return from the setting mode to the main menu or a submenu is possible by pressing the PROGRAM push button until the green digits on the display stop flashing.

NOTE! During any local man-machine communication over the push buttons and the display on the front panel a five minute time-out function is active. Thus, if no push button has been pressed during the last five minutes, the relay returns to its normal state automatically. This means that the display turns dark, the relay escapes from a display mode, a programming routine or any routine going on, when the relay is left untouched. This is a convenient way out of any situation when the user does not know what to do.

Before a relay module is inserted into the relay case, one must assure that the module has been given the correct settings. If there however is any doubt about the settings of the module to be inserted, the setting values should be read using a spare relay unit or with the relay trip circuits disconnected. If this cannot be done the relay can be sett into a non-tripping mode by pressing the PROGRAM push button and powering up the relay module simultaneously. The display will show three dashes "- - -" to indicate the non-tripping mode. The serial communication is operative and all main and submenues are accessible. In the non-tripping mode unnecessary trippings are avoided and the settings can be checked. *The normal protection relay mode is entered automatically after a timeout of five minutes or ten seconds after the dark display position of the main menu has been entered.*

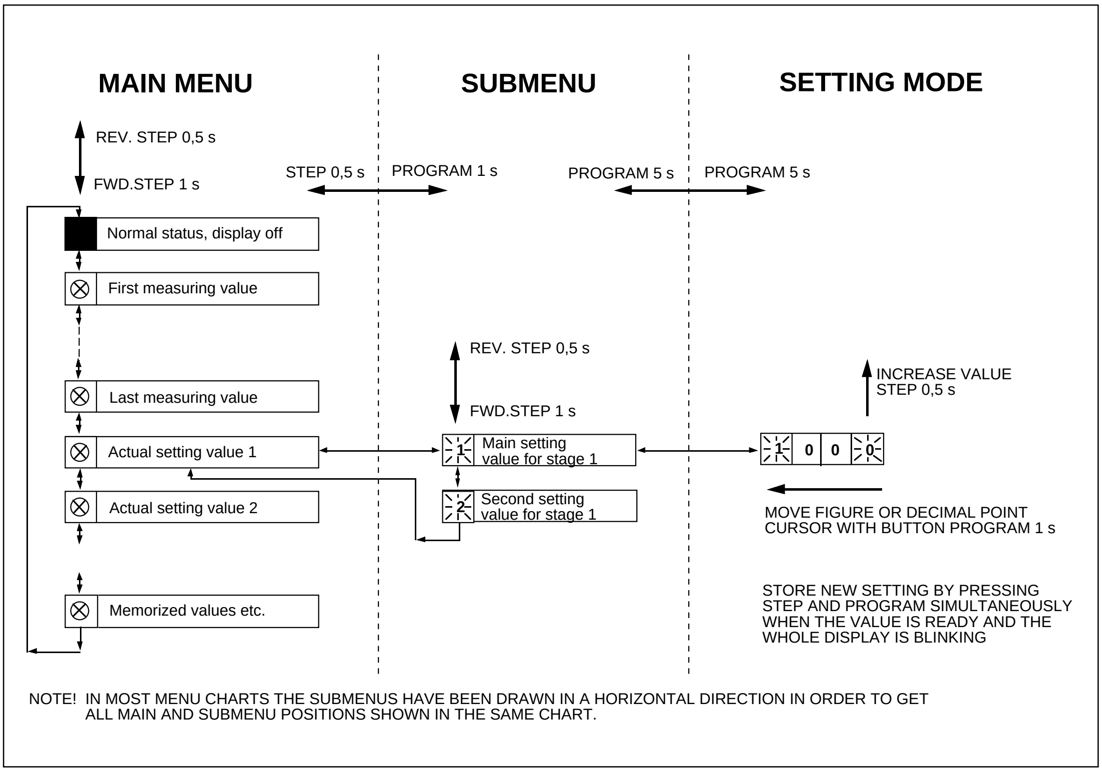


Fig.3. Basic principles of entering the main menus and submenus of a relay module.

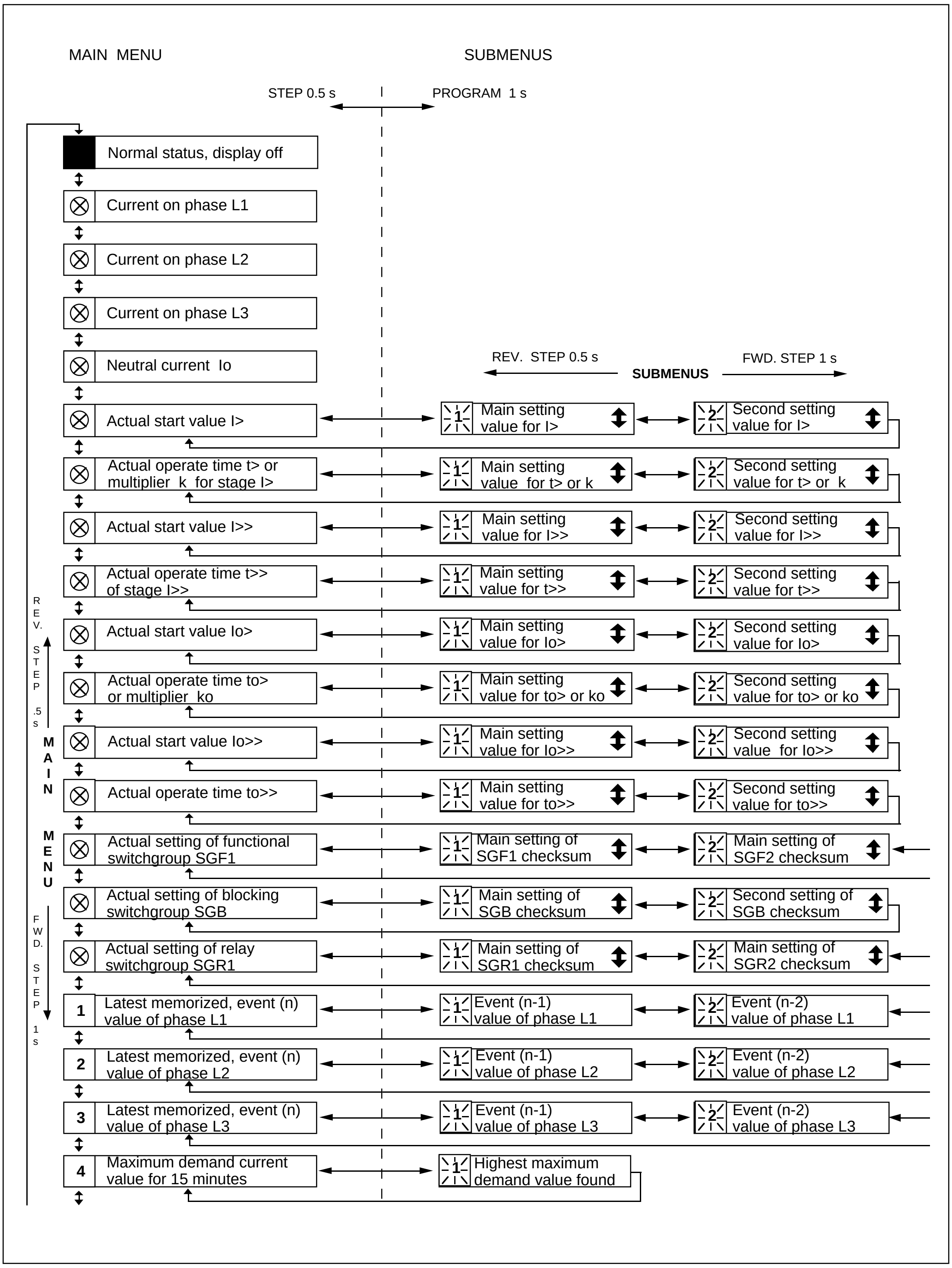
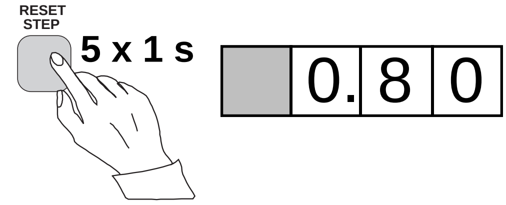


Fig. 4. Example of part of the main and submenus for the settings of the overcurrent and earth-fault relay module SPCJ 4D29. The settings currently in use are in the main manu and they are displayed by pressing the STEP push button. The main menu also includes the measured current values, the registers 1...9, 0 and A. The main and second setting values are located in the submenus and are called up on the display with the PROGRAM push button.

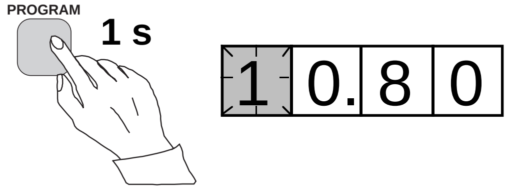
Example 1

Operation in the setting mode. Manual setting of the main setting of the start current value I> of an overcurrent relay module. The initial value for the main setting is 0.80 x I_n and for the second setting 1.00 x I_n. The desired main start value is 1.05 x I_n.

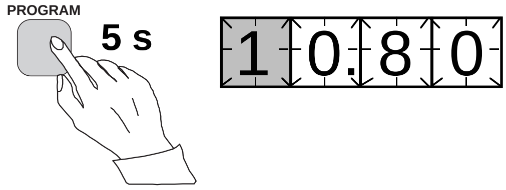
a)
Press push button STEP repeatedly until the LED close to the I> symbol is lit and the current start value appears on the display.



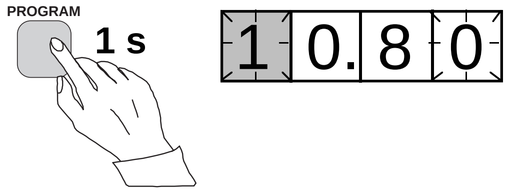
b)
Enter the submenu to get the main setting value by pressing the PROGRAM push button more than one second and then releasing it. The red display digit now shows a flashing number 1, indicating the first submenu position and the green digits show the set value.



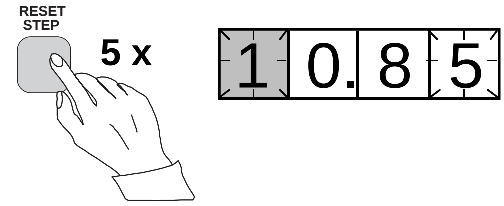
c)
Enter the setting mode by pressing the PROGRAM push button for five seconds until the display starts flashing.



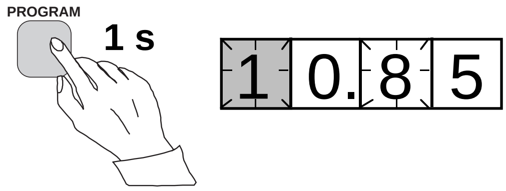
d)
Press the PROGRAM push button once again for one second to get the rightmost digit flashing.



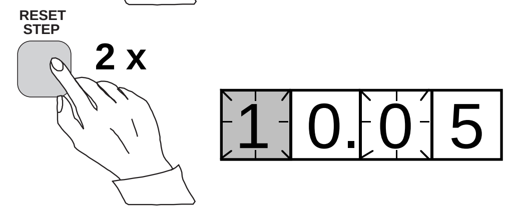
e)
Now the flashing digit can be altered. Use the STEP push button to set the digit to the desired value.



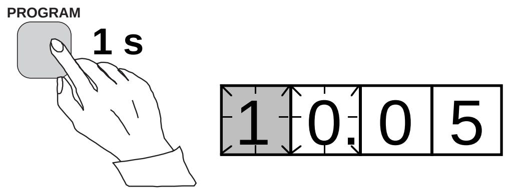
f)
Press the PROGRAM push button to make the middle one of the green digits flash.



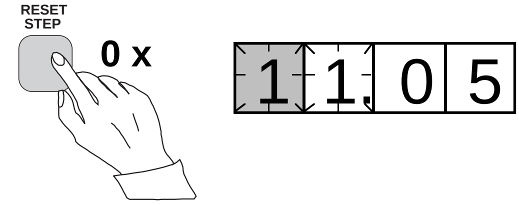
g)
Set the middle digit with of the STEP push button.



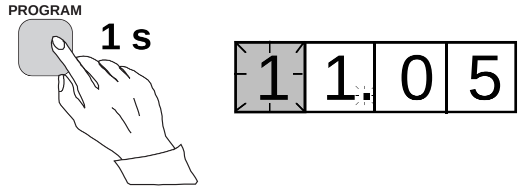
h)
Press the PROGRAM push button to make the leftmost green digit flash.



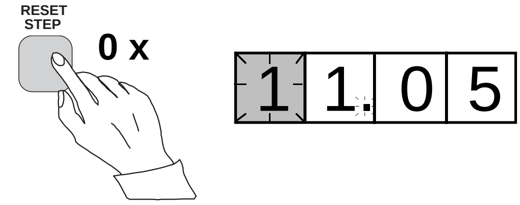
i)
Set the digit with the STEP push button.



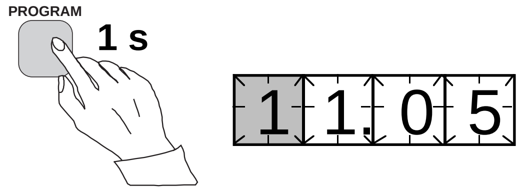
j)
Press the PROGRAM push button to make the decimal point flash.



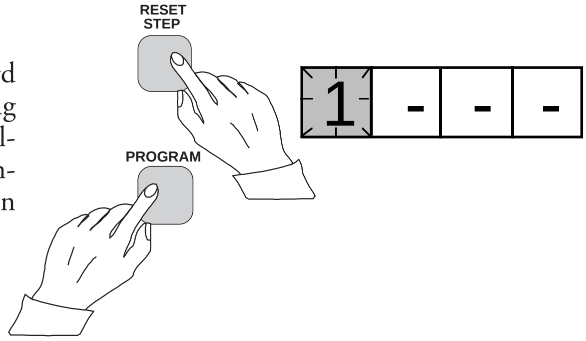
k)
If needed, move the decimal point with the STEP push button.



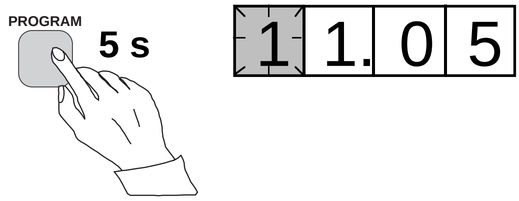
l)
Press the PROGRAM push button to make the whole display flash. In this position, corresponding to position c) above, one can see the new value before it is recorded. If the value needs changing, use the PROGRAM push button to alter the value.



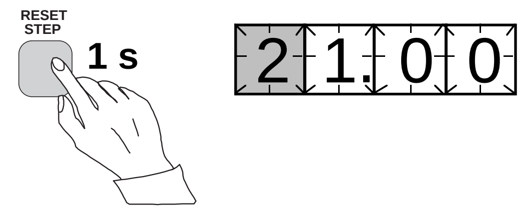
m)
When the new value has been corrected, record it in the memory of the relay module by pressing the PROGRAM and STEP push buttons simultaneously. At the moment the information enters the memory, the green dashes flash once in the display, i.e. 1 - - -.



n)
Recording of the new value automatically initiates a return from the setting mode to the normal submenu. Without recording one can leave the setting mode any time by pressing the PROGRAM push button for about five seconds, until the green display digits stop flashing.



o)
If the second setting is to be altered, enter submenu position 2 of the setting I> by pressing the STEP push button for approx. one second. The flashing position indicator 1 will then be replaced by a flashing number 2 which indicates that the setting shown on the display is the second setting for I>.

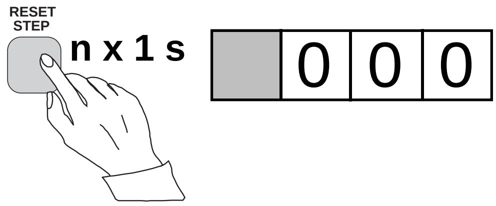


Enter the setting mode as in step c) and proceed in the same way. After recording of the requested values return to the main menu is obtained by pressing the STEP push button until the first digit is switched off. The LED still shows that one is in the I> position and the display shows the new setting value currently in use by the relay module.

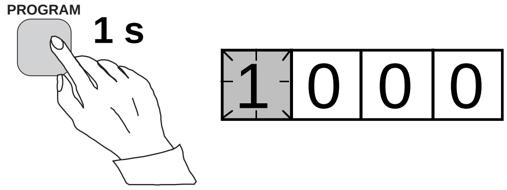
Example 2

Operation in the setting mode. Manual setting of the main setting of the checksum for the switchgroup SGF1 of a relay module. The initial value for the checksum is 000 and the switches SGF1/1and SGF1/3 are to be set in position 1. This means that a checksum of 005 should be the final result.

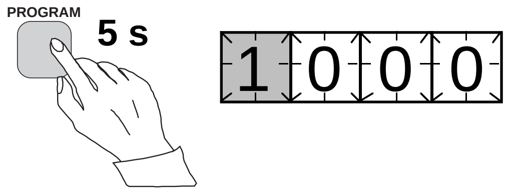
a)
Press push button STEP until the LED close to the SGF symbol is lit and the checksum appears on the display.



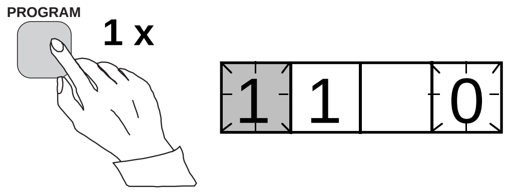
b)
Enter the submenu to get the main checksum of SGF1 by pressing the PROGRAM push button for more than one second and then releasing it. The red display now shows a flashing number 1 indicating the first submenu position and the green digits show the checksum.



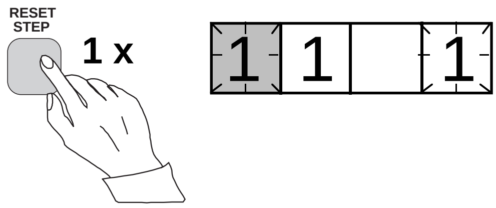
c)
Enter the setting mode by pressing the PROGRAM push button for five seconds until the display starts flashing.



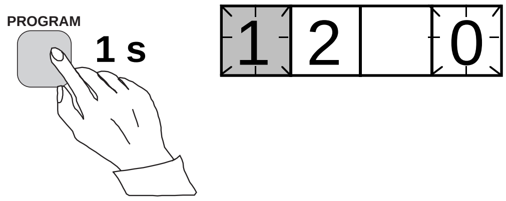
d)
Press the PROGRAM push button once again to get the first switch position. The first digit of the display now shows the switch number. The position of the switch is shown by the rightmost digit.



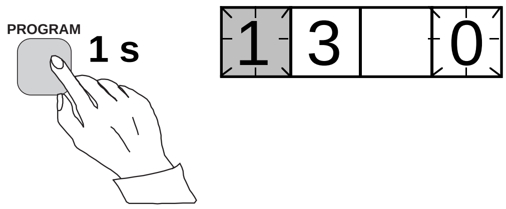
e)
The switch position can now be toggled between 1 and 0 by means of the STEP push button and it is left in the requested position 1.



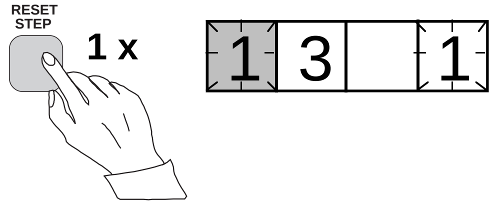
f)
When switch number 1 is in the requested position, switch number 2 is called up by pressing the PROGRAM push button for one second. As in step e), the switch position can be altered by using the STEP push button. As the desired setting for SGF1/2 is 0 the switch is left in the 0 position.



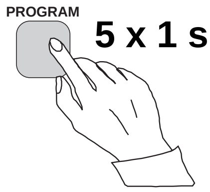
g)
Switch SGF1/3 is called up as in step f) by pressing the PROGRAM push button for about one second.



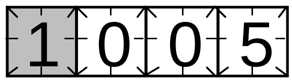
h)
The switch position is altered to the desired position 1 by pressing the STEP push button once.



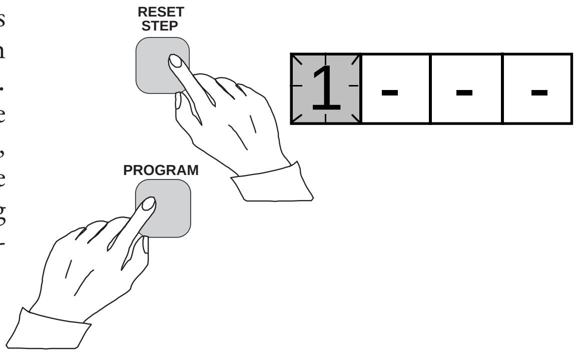
i)
Using the same procedure the switches SGF 1/ 4...8 are called up and, according to the example, left in position 0.



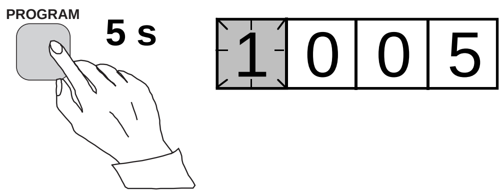
j)
In the final setting mode position, corresponding to step c), the checksum based on the set switch positions is shown.



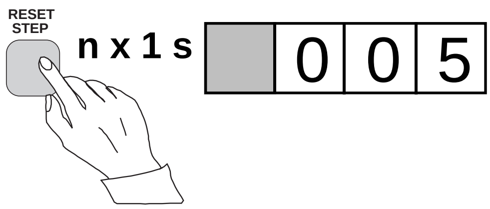
k)
If the correct checksum has been obtained, it is recorded in the memory by pressing the push buttons PROGRAM and STEP simultaneously. At the moment the information enters the memory, the green dashes flash in the display, i.e.1 - - -. If the checksum is incorrect, the setting of the separate switches is repeated using the PROGRAM and STEP push buttons starting from step d).



l)
Recording the new value automatically initiates a return from the setting mode to the normal menu. Without recording one can leave the setting mode any time by pressing the PROGRAM push button for about five seconds, until the green display digits stop flashing.



m)
After recording the desired values return to the main menu is obtained by pressing the STEP push button until the first digit is turned off. The LED indicator SGF still shows that one is in the SGF position and that the display shows the new checksum for SGF1 currently in use by the relay module.



Recorded information

The parameter values measured at the moment when a fault occurs or at the trip instant are recorded in the registers. The recorded data, except for some parameters, are set to zero by pressing the push buttons STEP and PROGRAM simultaneously. The data in normal registers are erased if the auxiliary voltage supply to the relay is interrupted, only the set values and certain other essential parameters are maintained in non-volatile registers during a voltage failure.

The number of registers varies with different relay module types. The functions of the registers are illustrated in the descriptions of the different relay modules. Additionally, the system front panel of the relay contains a simplified list of the data recorded by the various relay modules of the protection relay.

All D type relay modules are provided with two general registers: register 0 and register A.

Register 0 contains, in coded form, the information about e.g. external blocking signals, status information and other signals. The codes are explained in the manuals of the different relay modules.

Register A contains the address code of the relay modul which is reqiured by the serial communication system.

Submenu 1 of register A contains the data transfer rate value, expressed in kilobaud, of the serial communication.

Submenu 2 of register A contains a bus communication monitor for the SPAbus. If the protection relay, which contains the relay module, is linked to a system including a contol data communicatoe, for instance SRIO 1000M and the data communication system is operating, the counter reading of the monitor will be zero. Otherwise the digits 1...255 are continuously scrolling in the monitor.

Submenu 3 contains the password required for changing the remote settings. The address code, the data transfer rate of the serial communication and the password can be set manually or via the serial communication bus. For manual setting see example 1.

The default value is 001 for the address code, 9.6 kilobaud for the data transfer rate and 001 for the password.

In order to secure the setting values, all settings are recorded in two separate memory banks within the non-volatile memory. Each bank is complete with its own checksum test to verify the condition of the memory contents. If, for some reason, the contents of one bank is disturbed, all settings are taken from the other bank and the contents from here is transferred to the faulty memory region, all while the relay is in full operation condition. If both memory banks are simultaneously damaged the relay will be be set out of operation, and an alarm signal will be given over the serial port and the IRF output relay

Trip test function

Register 0 also provides access to a trip test function, which allows the output signals of the relay module to be activated one by one. If the auxiliary relay module of the protection assembly is in place, the auxiliary relays then will operate one by one during the testing.

When pressing the PROGRAM push button for about five seconds, the green digits to the right start flashing indicating that the relay module is in the test position. The indicators of the settings indicate by flashing which output signal can be activated. The required output function is selected by pressing the PROGRAM push button for about one second.

The indicators of the setting quantities refer to the following output signals:

Setting I>	Starting of stage I>
Setting t>	Tripping of stage I>
Setting I>>	Starting of stage I>>
Setting t>>	Tripping of stage I>>
etc.	
No indication	Self-supervision IRF

The selected starting or tripping is activated by simultaneous pressing of the push buttons STEP and PROGRAM. The signal remains activated as long as the two push butttons are pressed. The effect on the output relays depends on the configuration of the output relay matrix switches.

The self-supervision output is activated by pressing the STEP push button 1 second when no setting indicator is flashing. The IRF output is activated in about 1 second after pressing of the STEP push button.

The signals are selected in the order illustrated in Fig. 4.

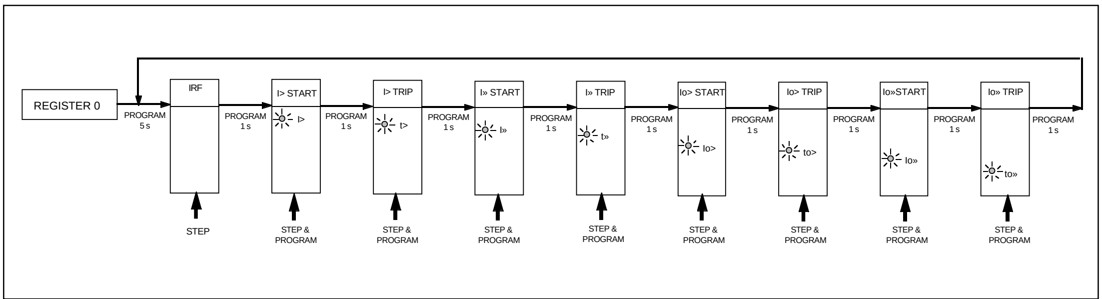


Fig. 5. Sequence order for the selection of output signals in the Trip test mode

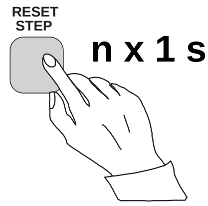
If, for instance, the indicator of the setting t> is flashing, and the push buttons STEP and PROGRAM are being pressed, the trip signal from the low-set overcurrent stage is activated. Return to the main menu is possible at any stage of the trip test sequence scheme, by pressing the PROGRAM push button for about five seconds.

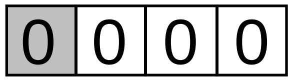
Note!
The effect on the output relays then depends on the configuration of the output relay matrix switchgroups SGR 1...3.

Example 3

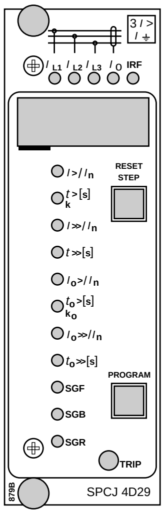
Trip test function. Forced activation of the outputs.

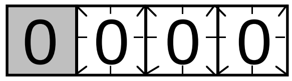
a)
Step forward on the display to register 0.

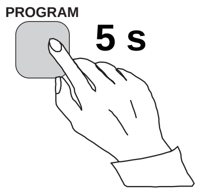




b)
Press the PROGRAM push button for about five seconds until the three green digits to the right.

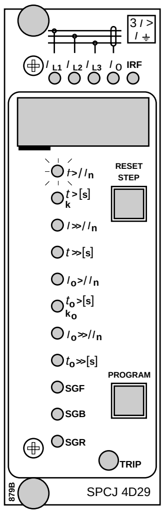


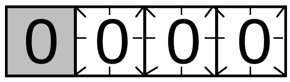




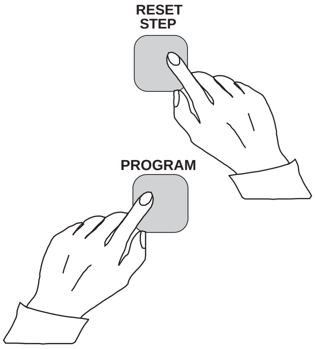
c)
Hold down the STEP push button. After one second the red IRF indicator is lit and the IRF output is activated. When the step push button is released the IRF indicator is switched off and the IRF output resets.

d)
Press the PROGRAM push button for one second and the indicator of the topmost setting start flashing.

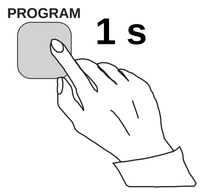


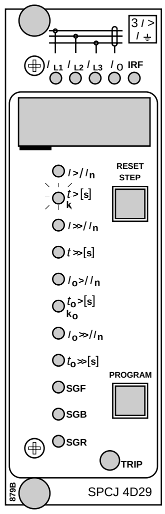


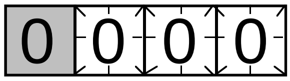
e)
If a start of the first stage is required, now press the push-buttons PROGRAM and STEP simultaneously. The stage output will be activated and the output relays will operate according to the actual programming of the relay output switchgroups SGR.



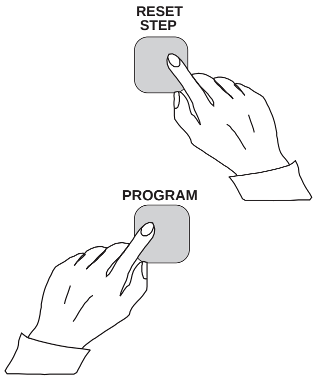
f)
To proceed to the next position press the PROGRAM push button for about 1 second until the indicator of the second setting starts flashing.

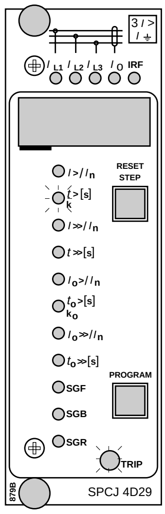


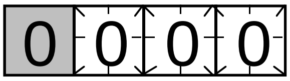




g)
Press the push buttons PROGRAM and STEP simultaneously to activate tripping of stage 1 (e.g. the I> stage of the overcurrent module SPCJ 4D29). The output relays will operate according to the actual programming of the relay switchgroups SGR. If the main trip relay is operated the trip indicator of the measuring module is lit.







h)
The starting and tripping of the remaining stages are activated in the same way as the first stage above. The indicator of the corresponding setting starts flashing to indicate that the concerned stage can be activated by pressing the STEP and PROGRAM buttons simultaneously. For any forced stage operation, the output relays will respond according to the setting of the relay output switchgroups SGR. Any time a certain stage is selected that is not wanted to operate, pressing the PROGRAM button once more will pass by this position and move to the next one without carrying out any operation of the selected stage.

It is possible to leave the trip test mode at any step of the sequence scheme by pressing the PROGRAM push button for about five seconds until the three digits to the right stop flashing.

Operation indication

A relay module is provided with a multiple of separate operation stages, each with its own operation indicator shown on the display and a common trip indicator on the lower part of the front plate of the relay module.

The starting of a relay stage is indicated with one number which changes to another number when the stage operates. The indicator remains glowing although the operation stage resets. The indicator is reset by means of the RESET push button of the relay module. An unreset operation indicator does not affect the function of the protection relay module.

In certain cases the function of the operation indicators may deviate from the above principles. This is described in detail in the descriptions of the separate modules.

Fault codes

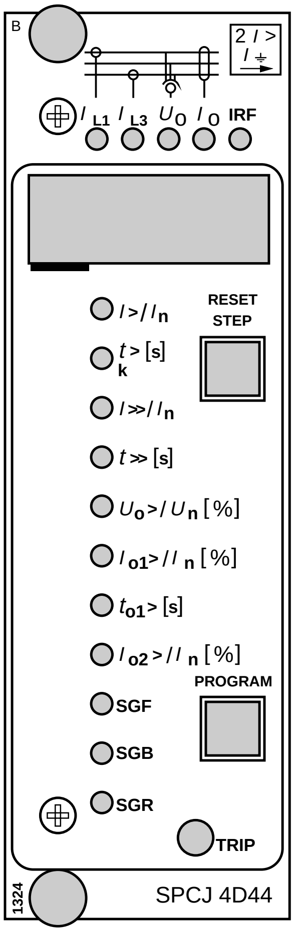
In addition to the protection functions the relay module is provided with a self-supervision system which continuously supervises the function of the microprocessor, its program execution and the electronics.

Shortly after the self-supervision system detects a permanent fault in the relay module, the red IRF indicator on the front panel is lit . At the same time the module puts forward a control signal to the output relay of the self-supervision system of the protection relay.

In most fault situations a fault code, indicating the nature of the fault, appears on the display of the module. The fault code, which consists of a red figure "1" and a three digit green code number, cannot be removed from the display by resetting. When a fault occurs, the fault code should be recorded and stated when service is ordered. When in a fault mode, the normal relay menus are operative, i.e. all setting values and measured values can be accessed although the relay operation is inhibited. The serial communication is also operative making it possible to access the relay information also from a remote site. The internal relay fault code shown on the display remains active until the internal fault possibly disappears and can also be remotely read out as variable V 169.

SPCJ 4D44
Overcurrent relay module

User´s manual and Technical description



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SPCJ 4D44
Non-directional phase and directional neutral overcurrent relay module

Contents

Characteristics

Low-set phase overcurrent stage I> with definite time and inverse time characteristic

High-set phase overcurrent stage I>> with instantaneous operation or definite time characteristic

Directional low-set neutral overcurrent stage I_{01}> with definite time characteristic

Directional or non-directional high-set neutral overcurrent stage I_{02}>

Digital display of measured quantities, relay setting values and sets of data recorded during fault situations

All settings may be entered either using the push-buttons and the display on the front panel of the module or a personal computer

Continuous self-supervision including both module hardware and software. At a permanent fault the alarm output relay operates and the other relay outputs are blocked.

Description of operation

Overcurrent unit

The overcurrent unit of the combined overcurrent and directional earth-fault relay module SPCJ 4D44 is designed for single-phase or two-phase operation. It contains two overcurrent stages, i.e. a low-set stage I> and a high-set-stage I>>.

The low-set or high-set stage starts if the current on one of the phases exceeds the setting value of the stage concerned. When starting the concerned stage provides a start signal and simultaneously the digital display on the front panel indicates starting. If the overcurrent situation lasts long enough to exceed the set operate time, the stage that started calls for CB tripping by providing a tripping signal. At the same time the operation indicator LED goes on with a red light. The red operation indicator remains lit although the stage resets.

The operation of both overcurrent stages can be blocked by applying a blocking signal BS1, BS2 or RRES to the unit. The blocking configuration is set by means of switchgroups SGB1, SGB2 and SGB3.

The operation of the low-set stage I> can be based on a definite time or inverse time characteristic. The mode of operation is programmed with switches SGF1/1...3. At definite time mode of operation the operating time t1> is set in seconds within the setting range 0.05...300 s. When inverse time mode of operation (IDMT) is used four internationally standardized and two special type time/current characteristics are available. The programming switches SGF1/1...3 are also used for selecting the desired operation characteristic.

Note !
If the setting is higher than 2.5 x I_n, the maximum continuous carry 4 x I_n and the levelling out of the IDMT curves at high current levels must be noted.

CAUTION !
Never use start current settings above 2.5 x I_n at inverse time characteristic, although allowed by the relay.

Note !
The high-current end of any inverse time characteristic is determined by the high-set stage which, when started, inhibits the low-set stage operation. Thus, the trip time is equal to the set operate time t>> for any current higher than I>>. In order to get a trip signal, the stage I>> must also, of course, be linked to a trip output relay.

The operate time of the high-set stage t>> is separately set within the range 0.04...300 s.

The operation of both overcurrent stages is provided with a latching facility keeping the tripping output energized, although the signal which caused the operation disappears. The output relays can be reset in five different ways; a) by pressing the PROGRAM push-button, b) by pressing the RESET and PROGRAM push-buttons simultaneously, by remote control over the SPA bus using c) the command V101 or d) the command V102 and further e) by remote control over the external control input. When a) or c) is used no stored data are erased, but when resetting according to b), d) or e) is used the recorded data are erased.

The setting value of the high-set stage I>> may be subject to automatic doubling when the protected object is connected to the network, i.e. in a starting situation. Thus the setting value of the I>> stage may be lower than the connection inrush current. The automatic doubling function is selected with switch SGF1/5. The starting situation is defined as a situation where the phase currents increase from a value below 0.12 x I> to a value exceeding 1.5 x I> in less than 60 ms. The starting situation ends when the currents fall below 1.25 x I>.

The operation of the high-set stage may be set out of operation by means of switch SGF1/7. When the high-set stage is out of operation the display shows a "- - -" readout, indicating that the operating value is infinite.

Earth-fault unit

The directional earth-fault unit of the phase overcurrent and earth-fault relay module SPCJ 4D44 includes two protection stages: a low-set current stage $I_{01}>$ and a high-set current stage $I_{02}>$.

The directional earth-fault unit measures the neutral current I_0, the residual voltage U_0 and the phase angle between residual voltage and neutral current. A protection stages starts if all of the three criteria below are fulfilled:
- the residual voltage U_0 exceeds the start level set for the $U_0>$ stage. The setting is the same for the stages $I_{01}>$ and $I_{02}>$.
- the neutral current I_0 exceeds the set start value of stage $I_{01}>$ or stage $I_{02}>$.
- if the phase angle between residual voltage and neutral current falls within the operation sector $\varphi_b \pm\Delta\varphi$, where φ_b is the characteristic basic angle of the network and $\Delta\varphi$ is the operation area.

The setting value of the characteristic basic angle φ_b of the network is selected according to the earthing principle used in the network, that is, -90° for isolated neutral networks, and 0° for resonant-earthed networks, which are earthed through an arc suppression coil (Petersen coil), with or without a parallel resistor.

The operation sector $\Delta\varphi$ can be set to ±80° or ±88° for both stages.

Note!
If $I_0 < 3\% \ I_n$ and SGF3/5 = 0 then the operation sector $\Delta\varphi = \pm 70°$.

When an earth-fault stage starts a starting signal is obtained and, simultaneously, the digital display on the front panel indicates starting. If the above mentioned criteria are fulfilled long enough to exceed the set operation time, the stage that started delivers a tripping signal. At the same time the operation indicator on the front panel is lit. The red operation indicator remains lit although the protection stage resets. On the basis of the angle between voltage and current, the direction towards the fault spot is determined, see Fig. 1 below.

The $I_{02}>$ stage can also be configured to measure the intermittent earth faults. See appendix 1.

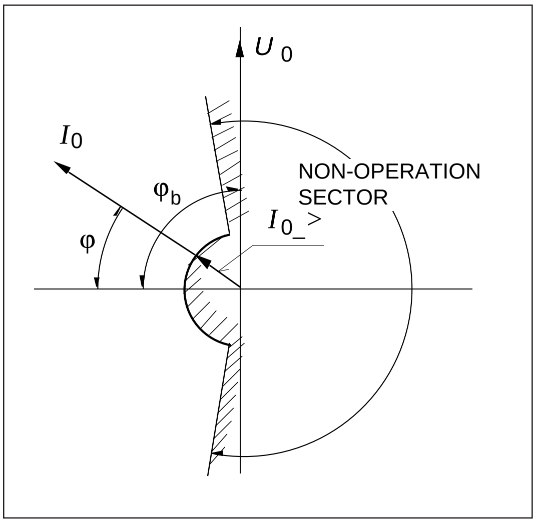


Fig. 1a. Operation characteristic of the directional earth-fault protection unit, when the basic angle φ_b = -90°.

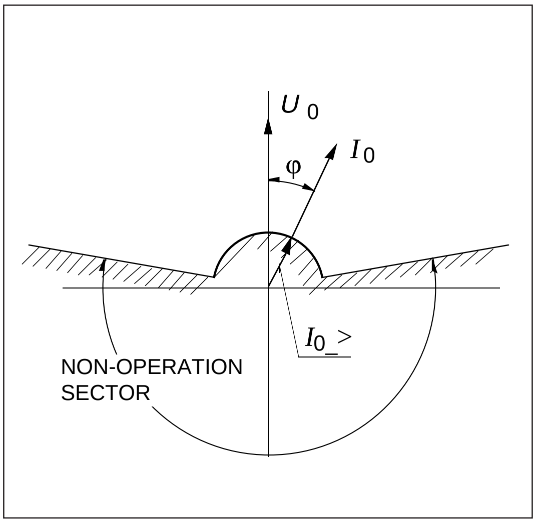


Fig. 1b. Operation characteristic of the directional earth-fault protection unit, when the basic angle φ_b = 0°.

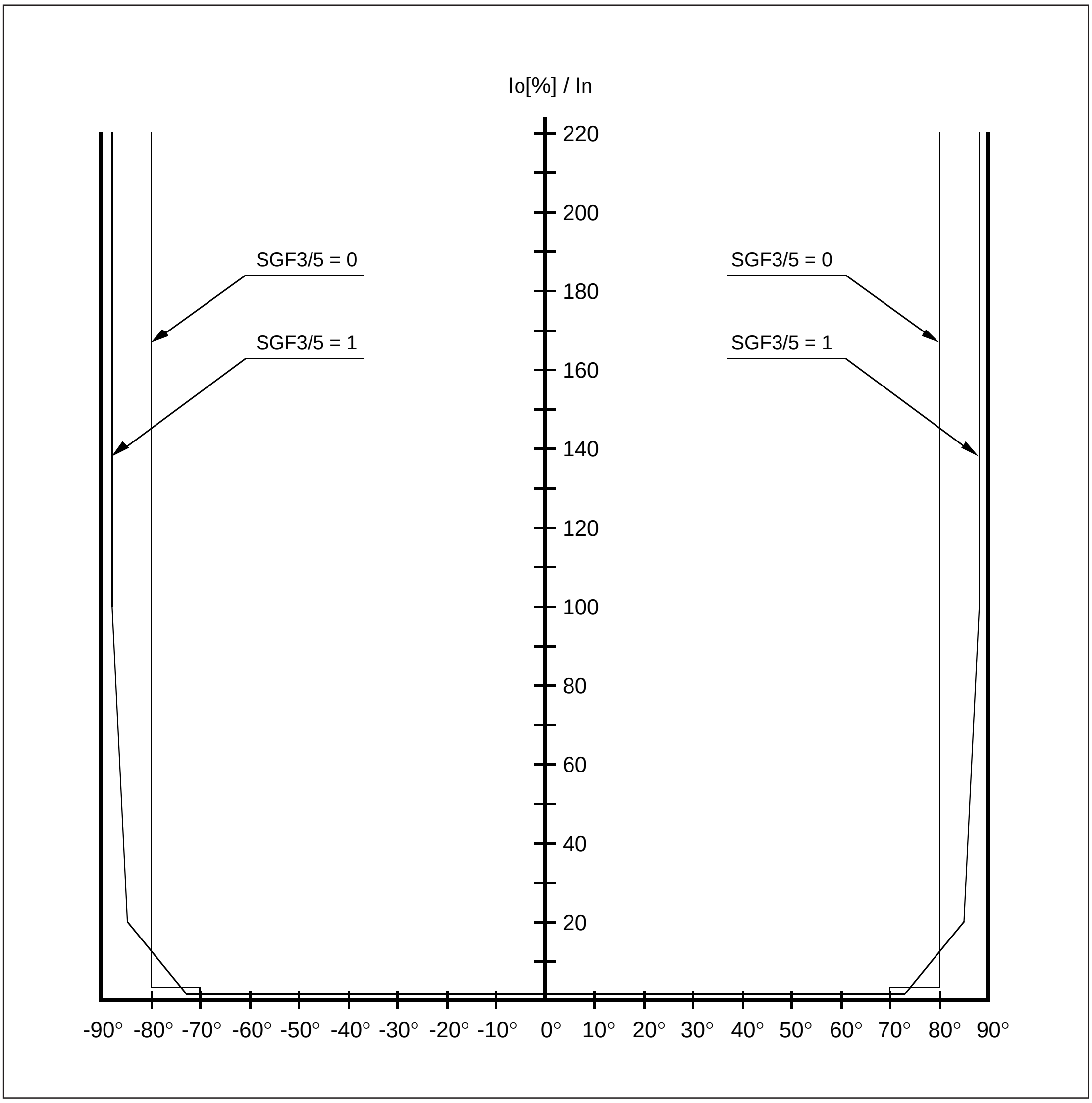


Fig. 1c. Operation characteristic of the directional earth-fault protection unit of the relay module SPCJ 4D44 shown in an I_0-φ diagram with the characteristic angle φ_b = 0°.

The basic angle φ_b i.e. -90°, -60°, -30° or 0° is set with the switches SGF2/1…2.

Harmonics of the neutral current measured by the earth-fault unit are effectively filtered out by means of a bandpass filter. The third harmonic, for example, is reduced by 17 dB of its original value. Harmonics of higher order are suppressed even more.

The operation of the protection stages can be blocked by routing a blocking signal BS1, BS2 or RRES to the concerned protection stage. Switchgroups SGB1, SGB2 or SGB3 are used for configuring the blocking signals.

The operation direction of the earth fault stages can be selected independently of each other by using switches SGF2/3 and SGF2/5.

The operation time t_{01}> of the low-set stage I_{01}> is set within the range 0.1...300 s. The operation time of the high-set stage is preset and <100 ms.

The outputs of both neutral overcurrent stages are provided with a latching feature keeping the operation output energized, though the fault signal which caused the operation of the protection has disappeared. The output relays can be reset in five different ways; a) by pressing the PROGRAM push-button, b) by pressing the RESET and PROGRAM push-buttons simultaneously, by remote control over the SPA bus using c) the command V101 or d) the command V102 and further e) by remote control over the external control input. When a) or c) is used no recorded data are erased, but when resetting according to b), d) or e) is used the recorded data are erased.

Note!
The function described in the chapter "Earth-fault unit" applies to program versions SW 089 A and B. For program versions SW 089 C and D, see Appendix 1, page 39. An optional function for the detection of intermittent earth faults has been added to the earth-fault stage I_{02}>.

For program version SW 089 F and later, see Appendix 2, page 40. Some changes have been made to the earth-fault stages I_{01}> and I_{02}> in order to improve the protective functions for the faulted line and healthy lines.

The operation of the high-set stage I_{02}> may be set out of operation by means of switch SGF1/8. When the stage is out of operation the display shows a "- - -", indicating that the operation value is infinite.

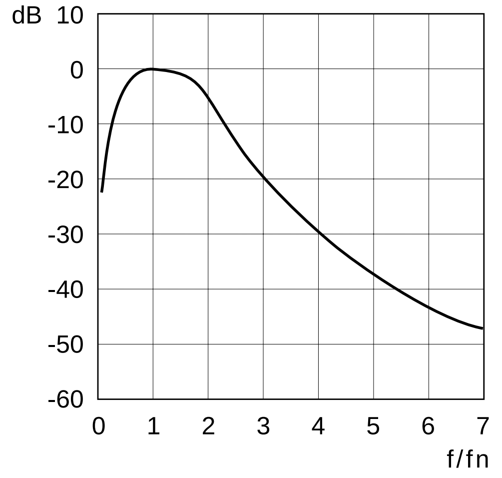
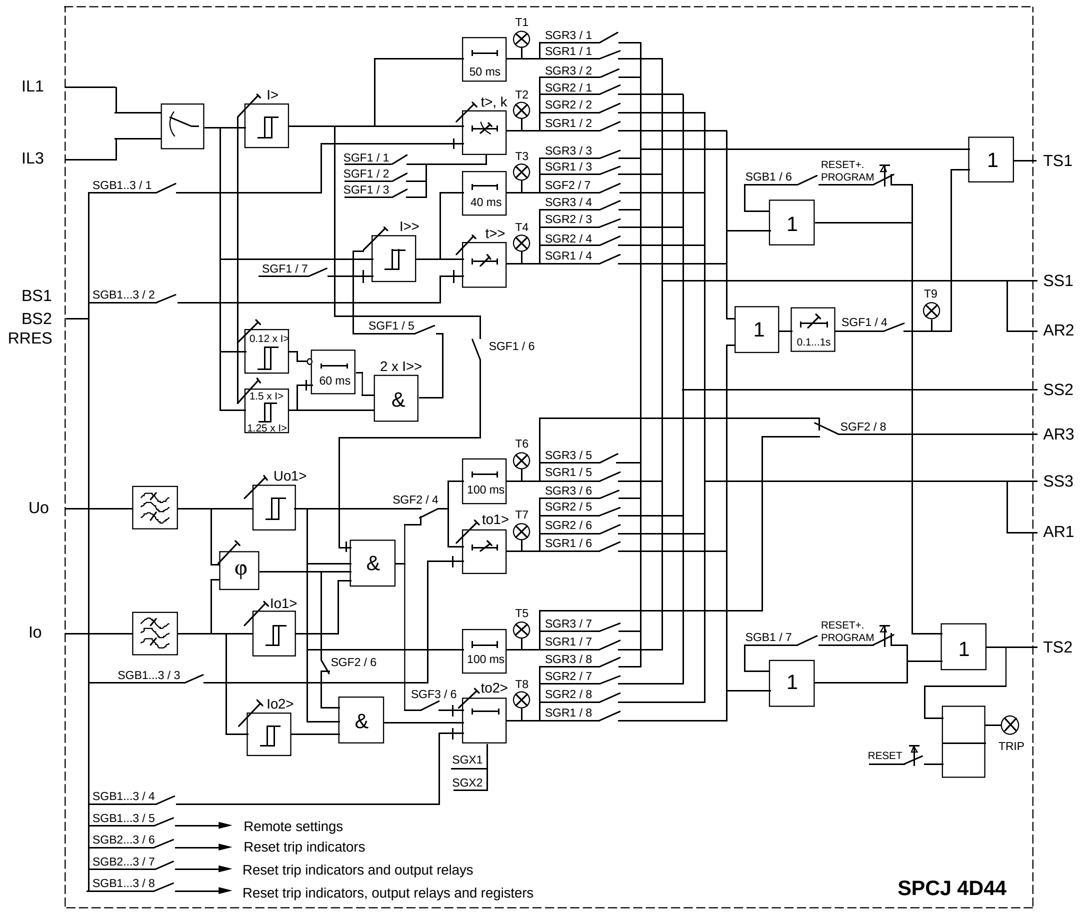


Fig. 2. Filter characteristics of the energizing inputs of the residual current I_0 and voltage U_0 of the relay module.

Circuit breaker failure protection

The relay module is also provided with a circuit breaker failure protection (CBFP), which provides a tripping signal via TS1 after the set operation time 0.1...1 s counted from the normal tripping signal TS2, if the fault has not been cleared within that time. The operation time of the circuit breaker failure protection is set in Register A, submenu 5.The output contact of the circuit breaker failure protection is normally used for tripping an upstream circuit breaker. The CBFP can also be used for establishing a redundant trip system by providing the circuit breaker with two tripping coils one being controlled by TS2 and the other by TS1. The circuit breaker failure protection is taken into use or taken out of use by means of switch SGF1/4.

Block diagram



N.B.! For t_{02}> and SGX/1...2, see Appendix 2

Fig 3. Block diagram for the two-phase phase overcurrent and earth-fault relay module SPCJ 4D44.

I_{L1}, I_{L3}	Measured phase currents
I_0	Measured neutral current
U_0	Measured residual voltage
BS1, BS2 and RRES	External blocking or resetting signals
SGF1...3	Programming switchgroups SGF1...SGF3
SGB1...3	Programming switchgroups SGB1...SGB3
SGR1...3	Programming switchgroups SGR1...SGR3
SS1...SS3,	
TS1, TS2	Output signals
TRIP	Operation indicator

Note !
All input and output signals of the module are not necessarily wired to the terminals of every protection relay unit using this module. The signals wired to the terminals are shown in the diagram illustrating the flow of signals between the various modules of the protection relay unit.

Front panel

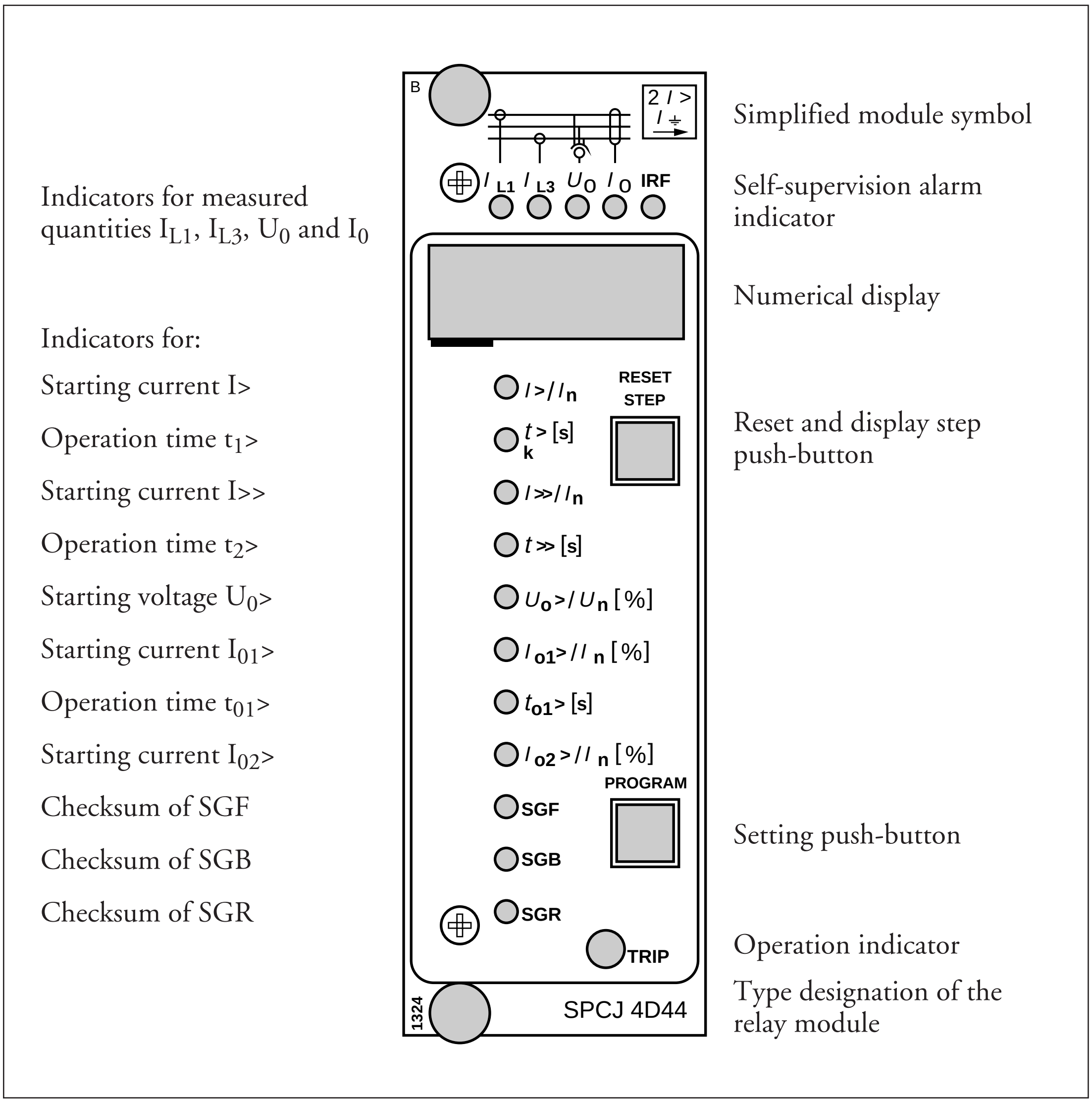


Fig 4. Front panel of the two-phase overcurrent and directional earth-fault module SPCJ 4D44.

Operation indicators

Each stage has its own starting indicator and operation indicator shown as a number on the display. Further all stages operate with a common LED operation indicator named "TRIP", glowing red when indicating that the module has operated.

The number indicating operation remains lit on the display when the protection stage resets, thus indicating that a certain protection stage has operated.

If the start situation of a stage is not long enough to cause a trip, the starting indication is normally self-reset when the stage resets. However, by means of switches SGF3/1...4 the starting indicators can be made latching, which means that they must be manually reset.

The numbers indicating starting and tripping are explained in the following table.

Indication	Explanation	
1	I> start	= The low-set stage of the overcurrent unit has started.
2	I> trip	= The low-set stage of the overcurrent unit has operated.
3	I>> start	= The high-set stage of the overcurrent unit has started.
4	I>> trip	= The high-set stage of the overcurrent unit has operated.
5	U_0> start	= The residual voltage stage has started.
6	I_{01}> start	= The low-set stage of the earth-fault unit has started.
7	I_{01}> trip	= The low-set stage of the earth-fault unit has operated.
8	I_{02}> trip	= The high-set stage of the earth-fault unit has operated.
9	CBFP	= The circuit breaker failure protection has operated.

The self supervision alarm indicator IRF indicates that the self-supervision system has detected a permanent fault. The indicator goes on with red light about 1 minute after the fault has been detected. At the same time the plug-in module delivers a signal to the self-supervision system output relay of the protection assembly.

Additionally, in most cases, a fault code showing the nature of the fault appears on the display of the module. The fault code consists of a red figure one and a green code number. When a fault occurs, the fault code should be recorded and stated when service is ordered.

Relay settings

The setting values are shown by the right-most three digits of the display. An indicator close to the setting value symbol shows when illuminated which setting value is presented on the display at the very moment.

Setting	Parameter	Setting range
$I> [I_n]$	The starting current of the low-set stage of the overcurrent unit as a multiple of the rated current I_n of the selected energizing input. - at definite time characteristic - at inverse time characteristic Note! At inverse time characteristic any setting above 2.5 x I_n will be regarded as being equal to 2.5 x I_n.	 0.5…5.0 x I_n 0.5…2.5 x I_n
t> [s]	The operation time of the I> stage, expressed in seconds, when the low-set stage of the overcurrent unit is operating with definite time characteristic (SGF1/1,2,3=0).	0.05…300 s
k	The time multiplier k1, when the low-set stage of the over-current unit is operating with inverse definite minimum time characteristic.	0.05…1.00
$I>> [I_n]$	The starting current of the high-set stage of the overcurrent unit as a multiple of the rated current of the selected energizing input. Additionally, the setting "infinite" (displayed as - - -) can be selected with switch SGF1/7, which takes the high-set stage I>> out of operation.	0.5…40.0 x I_n
t>> [s]	The operation time of the high-set stage I>> of the over-current unit, expressed in seconds.	0.04…300 s
U_0> [%]	The starting voltage of the residual voltage stage U_0 as a percentage of the rated voltage of the selected energizing input.	2.0…80.0% U_n
I_{01}> [%]	The starting current of the low-set stage I_{01}> of the earth-fault unit as a percentage of the rated current of the selected energizing input.	1.0…25.0% I_n
t_{01}> [s]	The operation time t_{01}> of the low-set stage I_{01}> of the earth-fault unit, expressed in seconds.	0.1…300 s
I_{02}> [%]	The starting current I_{02}> of the high-set stage as a percentage of the rated current of the selected energizing input. Additionally, the setting "infinite" (displayed as - - -) can be selected, with switch SGF1/8, which takes the high-set stage of the earth-fault unit out of operation.	2.0…150% I_n
t_{02}> [s]	se Appendix 2	0.1...2.5 s

Further the checksums of the selector switch-groups SGF1, SGB1,and SGR1 are indicated on the display when the indicators adjacent to the switchgroup symbols on the front panel are lit. The checksums for the switchgroups SGF2, SGF3, SGB2, SGB3, SGR2 and SGR3 are found in the submenus of the corresponding main switchgroups. Further, see clause "Main menus and submenus of settings and registers". An example of calculating the checksum is given in the general description of the D-type SPC relay modules.

Function selector switches

Additional functions required by individual applications are selected by using the switchgroups SGF, SGB and SGR indicated on the front panel. The numbering of the switches, i.e. 1...8, the switch positions, i.e. 0 and 1, are indicated on the display when the switches are set. Under normal service only the checksums are shown. The switchgroups SGF2, SGF3, SGB2, SGB3, SGR2 and SGR3 are found in the submenus of the main switchgroups SGB, SGF and SGR.

Functional switchgroups SGF1, SGF2 and SGF3

<table>
<tr><th>Switch</th><th>Function</th><th>Default setting</th></tr>
<tr><td>SGF1/1
SGF1/2
SGF1/3</td><td>Switches SGF1/1...3 are used for selecting the operation characteristic of the low-set stage I>, i.e. definite time characteristic or inverse definite minimum time (I.D.M.T.) characteristic. Further, at inverse definite minimum time characteristic the switches are used for selecting the required current/time characteristic of the stage.
<table>
<tr><th>SGF1/1</th><th>SGF1/2</th><th>SGF1/3</th><th>Characteristic</th><th>Time or curve</th></tr>
<tr><td>0</td><td>0</td><td>0</td><td>Definite time</td><td>0.05...300 s</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>I.D.M.T.</td><td>Extremely inv.</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>"</td><td>Very inverse</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>"</td><td>Normal inverse</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>"</td><td>Long-time inv.</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>"</td><td>RI-character.</td></tr>
<tr><td>0</td><td>1</td><td>1</td><td>"</td><td>RXIDG-character.</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>"</td><td>Long-time inv.</td></tr>
</table>
</td><td>0
0
0</td></tr>
<tr><td>SGF1/4</td><td>Selection /deselection of the circuit breaker failure protection.

When SGF1/4=1 the tripping signal TS2 starts a timer which, via TS1, provides a tripping signal after a set time, if the fault still persists.
When switch SGF1/4=0 only the normal tripping signal is provided.</td><td>0</td></tr>
<tr><td>SGF1/5</td><td>Selection of automatic doubling of the set starting value of the high-set stage I>> when the protected object is energized.

When SGF1/5=0, no doubling of the setting value I>> is obtained.
When SGF1/5=1, the setting value of the I>> stage doubles automatically. This makes it possible to give the high-set stage a setting value below the connection inrush current level of the protected object.</td><td>0</td></tr>
<tr><td>SGF1/6</td><td>Inhibition of the operation of the first earth-fault stage I_{01}> by the starting signal of the low-set overcurrent stage I>.

When SGF1/6=0, the e/f stage I_{01}> is not inhibited by the starting signal of the low-set stage I>.
When SGF1/6=1, the e/f stage I_{01}> is inhibited by the starting signal of the low-set stage I>.</td><td>0</td></tr>
<tr><td>SGF1/7</td><td>Selection/deselection of the high-set stage I>> of the overcurrent unit.

When SGF1/7=0, the high-set stage is alert.
When SGF1/7=1, the high-set stage is out of operation.</td><td>0</td></tr>
<tr><td>SGF1/8</td><td>Selection/deselection of the high-set stage I_{02}> of the earth-fault unit.

When SGF1/8=0, the high-set stage is alert.
When SGF1/8=1, the high-set stage is out of operation.</td><td>0</td></tr>
</table>

<table>
<tr><th>Switch</th><th>Function</th><th>Default setting</th></tr>
<tr><td>SGF2/1
SGF2/2</td><td>Selection of the base angle. The operation area of the protection is the basic angle $\varphi_b \pm$ the operation sector.

<table><tr><th>SGF2/1</th><th>SGF2/2</th><th>Basic angle</th></tr><tr><td>0</td><td>0</td><td>-90°</td></tr><tr><td>1</td><td>0</td><td>-60°</td></tr><tr><td>0</td><td>1</td><td>-30°</td></tr><tr><td>1</td><td>1</td><td>0°</td></tr></table></td><td>0
0</td></tr>
<tr><td>SGF2/3</td><td>Selection of operation direction for the low-set earth-fault stage $I_{01}>$.

When SGF2/3=0, the low-set stage $I_{01}>$ operates in the forward direction, as defined in the connection diagram.
When SGF2/3=1, the low-set stage $I_{01}>$ operates in the reverse direction, as defined in the connection diagram.</td><td>0</td></tr>
<tr><td>SGF2/4</td><td>Selection of directional operation characteristic for the low-set earth-fault stage or residual overvoltage function without current criterion.

When SGF2/4=0, the low-set stage of the earth-fault unit operates with directional characteristic including current measurement.
When SGF2/4=1, the low-set stage of the earth-fault unit functions as a residual overvoltage unit with the operation time $t_{01}>$.</td><td>0</td></tr>
<tr><td>SGF2/5</td><td>Selection of operation direction for the high-set stage $I_{02}>$ of the earth-fault unit.

When SGF2/5=0, the high-set stage $I_{02}>$ operates in the forward direction, as defined in the connection diagram.
When SGF2/5=1, the low-set stage $I_{02}>$ operates in the reverse direction, as defined in the connection diagram.</td><td>0</td></tr>
<tr><td>SGF2/6</td><td>Selection of directional or non-directional operation for the high-set earth-fault stage $I_{02}>$.

When SGF2/6=0, the operation characteristic of high-set stage $I_{02}>$ is directional.
When SGF2/6=1, the operation characteristic of high-set stage $I_{02}>$ is non-directional.</td><td>0</td></tr>
<tr><td>SGF2/7</td><td>Routing of the starting signal from the high-set stage of the overcurrent unit to the output AR1.

When SGF2/7=0, no starting signal from the high-set stage I>> is routed to the output AR1.
When SGF2/7=1, the starting signal from the high-set stage I>> is routed to the output AR1.</td><td>0</td></tr>
<tr><td>SGF2/8</td><td>Routing of the starting signal from the stage $I_{01}>$ or the stage $U_0>$ to the outputAR3.

When SGF2/8=0, the starting signal from the low-set stage $I_{01}>$ is routed to the output AR3.
When SGF2/8=1, the starting signal from the residual overvoltage stage $U_0>$ is routed to the output signal AR3.</td><td>0</td></tr>
</table>

Switch	Function	Default setting
SGF3/1 SGF3/2 SGF3/3 SGF3/4	Switches SGF3/1...4 are used for selecting the mode of operation of the starting indicators of the different stages. When the switches are in position 0, the starting indicators are automatically reset when the fault is cleared. In order to get a manually reset starting indication for a stage, the corresponding switch is set into position 1: When SGF3/1=1, the starting indicator of the low-set overcurrent stage I> is to be manually reset. When SGF3/2=1, the starting indicator of the high-set overcurrent stage I>> is to be manually reset. When SGF3/3=1, the starting indicator of the residual overvoltage stage U_0> is to be manually reset. When SGF3/4=1, the starting indicator of the low-set earth-fault stage I_{01}> is to be manually reset.	0 0 0 0
SGF3/5	Selection of operation sector for the directional earth-fault protection unit. When SGF3/5=0, the operation sector is ±80°. When SGF3/5=1, the operation sector is ±88°.	0
SGF3/6	Selection of operation principle for earth-fault stage I_{02}> *) SGF3/6=0 normal earth-fault stage SGF3/6=1 detection of intermittent earth faults *\) *This switch is available in version SW 089 C*	0
SGF3/7	SGF3/7 Available in program version SW 089 F, p. 40, appendix 2	0
SGF3/8	Not in use	0

Note!
Switchgroup SGX/1...6 is available in program version SW 089 F, see page 40 in Appendix 2.

Blocking or control input switchgroups SGB1, SGB2 and SGB3

Switchgroup SGB1 for configuring the control signal BS1

Switch	Function	Default setting
SGB1/1 SGB1/2 SGB1/3 SGB1/4	Switches SGB1/1…4 are used when the external control signal BS1 is to be used for blocking of the operation stages of the module one by one. When all the switches are in position 0 no stage is blocked. When SGB1/1=1, the operation of low-set overcurrent stage I> is blocked by the control signal BS1. When SGB1/2=1, the operation of high-set overcurrent stage I>> is blocked by the control signal BS1. When SGB1/3=1, the operation of the low-set earth-fault stage I_{01}> is blocked by the control signal BS1. When SGB1/4=1, the operation of the high-set earth-fault stage I_{02}> is blocked by the control signal BS1.	0 0 0 0
SGB1/5	Selection of main setting values or second setting values using an external control signal. When SGB1/5 = 0, the main or second setting values are determined according to the actual setting, that is, the setting is selected via command V150 over the serial interface or manually with the pushbuttons. When SGB1/5 = 1, an external control signal is used for selecting main setting or second setting values. The main settings are active, when no control voltage is applied to the control input BS1, whereas the second settings are active, when a control voltage is applied to the control input. *Note! When SGB1/5 is in position 1, the relay module does not accept main settings or second settings made over the serial interface or via the pushbuttons on the front panel.* *Note! Only one of the switches SGB1…3/5 is allowed to be in position 1.* *Note! Switch SGB1/5 must always be in the same position in the main settings and the second settings.*	0
SGB1/6	Selection of latching function for the output signal TS2 after being activated by the overcurrent unit. When SGB1/6=0, the operation signal of the I> stage and the I>> stage resets when the corresponding stage resets. When SGB1/6=1, the operation signal of the I> stage and the I>> stage must be manually reset by pressing the RESET and PROGRAM push-buttons simultaneously. The TS2 signal can also be reset by signal BS1. Note switch SGB1/8. When the display is off the signals can also be reset by pressing the PROGRAM push-button alone.	0
SGB1/7	Selection of latching function for the output signal TS2 after activated by the earth-fault unit. When SGB1/7=0, the operation signal of the I_{01}> stage and the I_{02}>> stage resets when the corresponding stage resets. When SGB1/7=1, the operation signal of the I_{01}> stage and the I_{02}>> stage must be manually reset by pressing the RESET and PROGRAM push-buttons simultaneously. The TS2 signal can also be reset by signal BS1. Note switch SGB1/8. When the display is off the signals can also be reset by pressing the PROGRAM push-button alone.	0
SGB1/8	Complete remote relay reset, including operation indicators, latched output relays and recorded values. A remote relay reset can be performed using the external control signal BS1 when switch SGB1/8=1.	

Switchgroup SGB2 for configuring the control signal BS2

Switch	Function	Default setting
SGB2/1 SGB2/2 SGB2/3 SGB2/4	Switches SGB2/1…4 are used when the external control signal BS2 is to be used for blocking the operation stages of the module one by one. When all the switches are in position 0 no stage is blocked. When SGB2/1=1, the operation of low-set overcurrent stage I> is blocked by the control signal BS2. When SGB2/2=1, the operation of high-set overcurrent stage I>> is blocked by the control signal BS2. When SGB2/3=1, the operation of the low-set earth-fault stage I_{01}> is blocked by the control signal BS2. When SGB2/4=1, the operation of the high-set earth-fault stage I_{02}> is blocked by the control signal BS2.	0 0 0 0
SGB2/5	Selection of main setting values or second setting values using an external control signal. When SGB2/5 = 0, the main or second setting values are determined according to the actual setting, that is, the setting is selected via command V150 over the serial interface or manually with the pushbuttons. When SGB2/5 = 1, an external control signal is used for selecting main setting or second setting values. The main settings are active, when no control voltage is applied to the control input BS2, whereas the second settings are active, when a control voltage is applied to the control input. *Note! When SGB2/5 is in position 1, the relay module does not accept main settings or second settings made over the serial interface or via the pushbuttons on the front panel.* *Note! Only one of the switches SGB1…3/5 is allowed to be in position 1.* *Note! Switch SGB2/5 must always be in the same position in the main settings and the second settings.*	0
SGB2/6	Remote resetting of the operation indicators by means of the external control signal BS2. When SGB2/6=0, the operation indicators are not reset by means of BS2. When SGB2/6=1, the operation indicators are reset by means of BS2.	0
SGB2/7	Remote resetting of the operation indicators and the output relays by means of the external control signal BS2. When SGB2/7=0, the operation indicators and the output relays are not reset by means of BS2. When SGB2/7=1, the operation indicators and the output relays are reset by means of BS2.	0
SGB2/8	Complete remote relay reset, including operation indicators, latched output relays and recorded values. A remote relay reset can be performed using the external control signal BS2 when switch SGB2/8=1.	0

Switchgroup SGB3 for configuring the control signal RRES

Switch	Function	Default setting
SGB3/1 SGB3/2 SGB3/3 SGB3/4	Switches SGB3/1…4 are used when the external control signal RRES is to be used for blocking the operation stages of the module one by one. When all the switches are in position 0 no stage is blocked. When SGB3/1=1, the operation of low-set overcurrent stage I> is blocked by the control signal RRES. When SGB3/2=1, the operation of high-set overcurrent stage I>> is blocked by the control signal RRES. When SGB3/3=1, the operation of the low-set earth-fault stage $I_{01}>$ is blocked by the control signal RRES. When SGB3/4=1, the operation of the high-set earth-fault stage $I_{02}>$ is blocked by the control signal RRES.	0 0 0 0
SGB3/5	Selection of main setting values or second setting values using an external control signal. When SGB3/5 = 0, the main or second setting values are determined according to the actual setting, that is, the setting is selected via command V150 over the serial interface or manually with the pushbuttons. When SGB3/5 = 1, an external control signal is used for selecting main setting or second setting values. The main settings are active, when no control voltage is applied to the control input RRES, whereas the second settings are active, when a control voltage is applied to the control input. *Note! When SGB3/5 is in position 1, the relay module does not accept main settings or second settings made over the serial interface or via the pushbuttons on the front panel.* *Note! Only one of the switches SGB1…3/5 is allowed to be in position 1.* *Note! Switch SGB3/5 must always be in the same position in the main settings and the second settings.*	0
SGB3/6	Remote resetting of the operation indicators by means of the external control signal RRES. When SGB3/6=0, the operation indicators are not reset by means of RRES. When SGB3/6=1, the operation indicators are reset by means of RRES.	0
SGB3/7	Remote resetting of the operation indicators and the output relays by means of the external control signal RRES. When SGB3/7=0, the operation indicators and the output relays are not reset by means of RRES. When SGB3/7=1, the operation indicators and the output relays are reset by means of RRES.	0
SGB3/8	Complete remote relay reset, including operation indicators, latched output relays and recorded values. A remote relay reset can be performed using the external control signal RRES when switch SGB3/8=1.	0

Output relay matrix switchgroups SGR1, SGR2 and SGR3

Switch	Function	Default setting
SGR1/1	When SGR1/1=1 the starting signal of stage I> is linked to SS1 + AR2.	1
SGR1/2	When SGR1/2=1 the tripping signal of stage I> is linked to TS2.	1
SGR1/3	When SGR1/3=1 the starting signal of stage I>> is linked to SS1 + AR2.	0
SGR1/4	When SGR1/4=1 the tripping signal of stage I>> is linked to TS2.	1
SGR1/5	When SGR1/5=1 the starting signal of stage I_{01}> is linked to SS1 + AR2.	0
SGR1/6	When SGR1/6=1 the tripping signal of stage I_{01}> is linked to TS2.	1
SGR1/7	When SGR1/7=1 the starting signal of stage U_0> is linked to SS1 + AR2.	0
SGR1/8	When SGR1/8=1 the tripping signal of stage I_{02}> is linked to TS2.	1

SGR2/1	When SGR2/1=1 the tripping signal of stage I> is linked to SS2.	1
SGR2/2	When SGR2/2=1 the tripping signal of stage I> is linked to SS3 + AR1.	0
SGR2/3	When SGR2/3=1 the tripping signal of stage I>> is linked to SS2.	1
SGR2/4	When SGR2/4=1 the tripping signal of stage I>> is linked to SS3 + AR1.	0
SGR2/5	When SGR2/5=1 the tripping signal of stage I_{01}> is linked to SS2.	0
SGR2/6	When SGR2/6=1 the tripping signal of stage I_{01}> is linked to SS3 + AR1.	1
SGR2/7	When SGR2/7=1 the tripping signal of stage I_{02}> is linked to SS2.	0
SGR2/8	When SGR2/8=1 the tripping signal of stage I_{02}> is linked to SS3 + AR1.	1

SGR3/1	When SGR3/1=1 the starting signal og stage I> is linked to TS1.	0
SGR3/2	When SGR3/2=1 the tripping signal of stage I> is linked to TS1.	0
SGR3/3	When SGR3/3=1 the starting signal of stage I>> is linked to TS1.	0
SGR3/4	When SGR3/4=1 the tripping signal of stage I>> is linked to TS1.	0
SGR3/5	When SGR3/5=1 the starting signal of stage I_{01}> is linked to TS1.	0
SGR3/6	When SGR3/6=1 the tripping signal of stage I_{01}> is linked to TS1.	0
SGR3/7	When SGR3/7=1 the starting signal of stage U_0> is linked to TS1.	0
SGR3/8	When SGR3/8=1 the tripping signal of stage I_{02}> is linked to TS1.	0

Measured data

The measured values are displayed by the three right-most digits of the display. The currently displayed value is indicated by an illuminated LED indicator on the front panel.

Indicator	Measured value
I_{L1}	Current on phase L1 as a multiple of the rated current I_n of the input used.
I_{L3}	Current on phase L1 as a multiple of the rated current I_n of the input used.
U_0	Residual voltage as a percentage of the rated voltage U_n of the input used.
I_0	Neutral current as a percentage of the rated current I_n of the input used.
I_0 (φ)	In the submenu of the neutral current the phase angle between residual voltage U_0 and neutral current I_0 is available. The phase angle value φ is the difference between the set basic angle φ_b and measured neutral current value I_0, -180°…0...+180°. *Note! The phase angle φ cannot be measured unless the input signals (I_0 and U_0) are at least 1%. Otherwise the display shows "- - -".*

Recorded data

The left-most red digit displays the register address and the other three digits the recorded information. A symbol "//" in the text indicates that the item following is found in a submenu.

Register	Recorded information
1	Maximum demand current value for a period of 15 minutes expressed as a multiple of the relay rated current I_n and based on the highest phase current. // Highest maximum demand value found since the latest complete relay reset.
2	Phase current I_{L1} measured as a multiple of the rated current of the protection. If the overcurrent unit starts but does not operate, the highest value during the starting situation is recorded and if the unit operates the value at the moment of operation is recorded in a memory stack. A new starting or operation moves the old value up one place in the stack and adds a new value to the stack. At a maximum five values are recorded. If a sixth starting or operation occurs, the oldest recorded value will be lost.
3	Phase current I_{L3} measured as a multiple of the rated current of the protection. If the overcurrent unit starts but does not operate, the highest value during the starting situation is recorded and if the unit operates the value at the moment of operation is recorded in a memory stack. A new starting or operation moves the old value up one place in the stack and adds a new value to the stack. At a maximum five values are recorded. If a sixth starting or operation occurs, the oldest recorded value will be lost.
4	Duration of the latest starting situation of stage I> as a percentage of the set operation time t_1> or at IDMT mode of operation the calculated operation time. A new starting resets the counter,which then starts counting from zero, and moves the old value up in the memory stack. At a maximum five values are memorized. If a sixth starting occurs the oldest value will be lost. When the concerned stage has tripped the counter reading is 100. // Number of startings of the stage I> in the range 0...255.
5	Duration of the latest starting situation of stage I>> as a percentage of the set operation time t>> or at IDMT mode of operation the calculated operation time. A new starting resets the counter,which then starts counting from zero, and moves the old value up in the memory stack. At a maximum five values are memorized. If a sixth starting occurs the oldest value will be lost. When the concerned stage has tripped the counter reading is 100. // Number of startings of the stage I>> in the range 0...255.
6	Measured residual voltage U_0 during the latest starting situation as a percentage of the rated voltage of the protection. If the earth fault unit operates the residual voltage value at the moment of tripping is stored in a memory stack. A new tripping moves the old value up one place in the stack and adds a new value to the stack. At a maximum five values are memorized. If a sixth tripping occurs, the oldest value will be lost.
7	Measured neutral current I_0 during the latest starting situation as a percentage of the rated current of the protection. If the earth fault unit operates the current value at the moment of tripping is stored in a memory stack. A new tripping moves the old value up one place in the stack and adds a new value to the stack. At a maximum five values are recorded. If a sixth operation occurs, the oldest value will be lost.
8	Duration of the latest starting situation of stage I_{01}> as a percentage of the set operation time t_1>. A new starting resets the counter,which then starts counting from zero, and moves the old value up in the memory stack. At a maximum five values are recorded. If a sixth starting occurs the oldest value will be lost. When the concerned stage has tripped the counter reading is 100. // Number of startings of the stage I_{01}> in the range 0...255.

Register	Recorded information
9	Duration of the latest starting situation of stage $I_{02}>$ as a percentage of the fixed operation time. A new starting resets the counter,which then starts counting from zero, and moves the old value up in the memory stack. At a maximum five values are memorized. If a sixth starting occurs the oldest value will be lost. When the concerned stage has tripped the counter reading is 100. // Number of startings of the stage $I_{02}>$ in the range 0...255.
11	Phase angle φ between the basic angle φ_b and the neutral current I_0. When the earth-fault unit operates, the phase angle φ at the moment of operation is recorded in a memory stack. A new operation moves the old value up one place in the stack and adds a new value to the stack. At a maximum five values are recorded. If a sixth operation occurs, the oldest recorded value will be lost.
0	Display of external blocking and control signals. The right-most digit indicates the state of the blockings input of the unit. Each input signals is represented by a number and the displayed number is the sum of the numbers representing the inputs which are energized. The following numbers represent the inputs: 0 = no input energized 1 = BS1 energized 2 = BS2 energized 3 = BS1 and BS2 energized 4 = RRES energized 5 = BS1 and RRES energized 6 = BS2 and RRES energized 7 = BS1, BS2 and RRES energized From this register"0" it is possible to move on to the TEST mode, where the starting and operation signals of the module are activated one by one. For further details see the description "General characteristics of D-type SPC relay modules".
A	Address code of the measuring relay module, required by the serial communication system. The submenus of this register include the following settings or functions. 1) Setting of serial communication data transfer rate:4.8 or 9.6 kBd. Default setting 9.6 kBd. 2) Bus traffic monitor. If the relay module is connected to a data communication system and the communication operates properly, the monitor value is 0. Otherwise the numbers 0...255 are rolling. 3) Password required for the remote control of the settings. The password (SPA parameter V160) must always be entered before a setting can be changed over the serial bus. 4) Selection of main / second setting bank. (0 = main settings, 1= second settings) 5) Setting of operate time for the circuit-breaker failure protection (CBFP). Setting range 0.1...1.0. Default setting 0.2 s 6) Programming switchgroup SGX. Detailed information on page 40, Appendix 2. Default setting 0.

The registers 1...11 are set to zero by pressing the push-buttons RESET and PROGRAM simultaneously. The registers are also cleared if the auxiliary power supply to the module is interrupted. The address code of the plug-in module, the data transfer rate of the serial communication, the password, the selector status and the SBFP and SGX settings are not erased by a voltage failure. The instructions for setting the address and the data transfer are described in the manual "General characteristics of D-type SPC relay modules".

Main menus and submenus of settings and registers

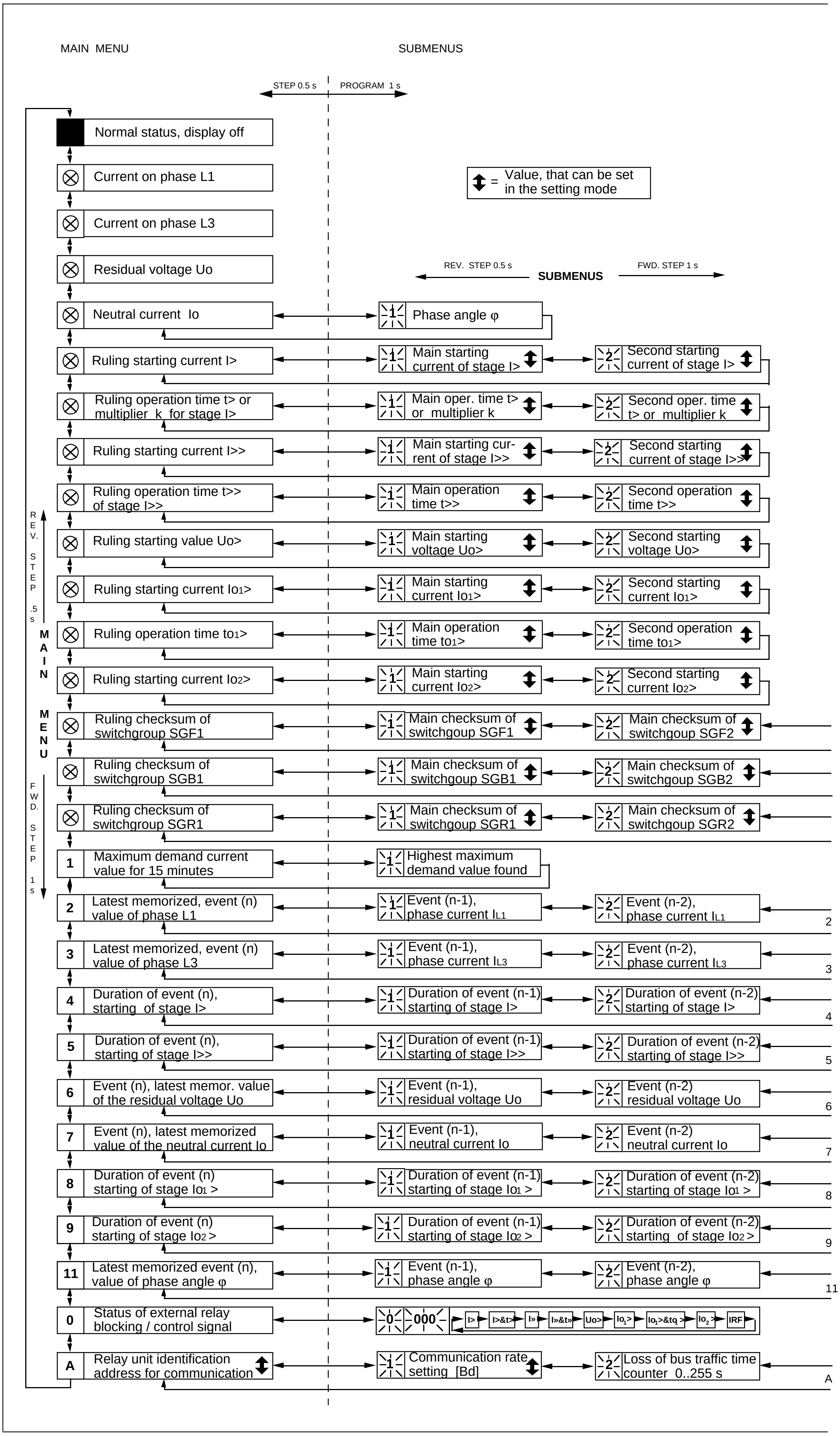
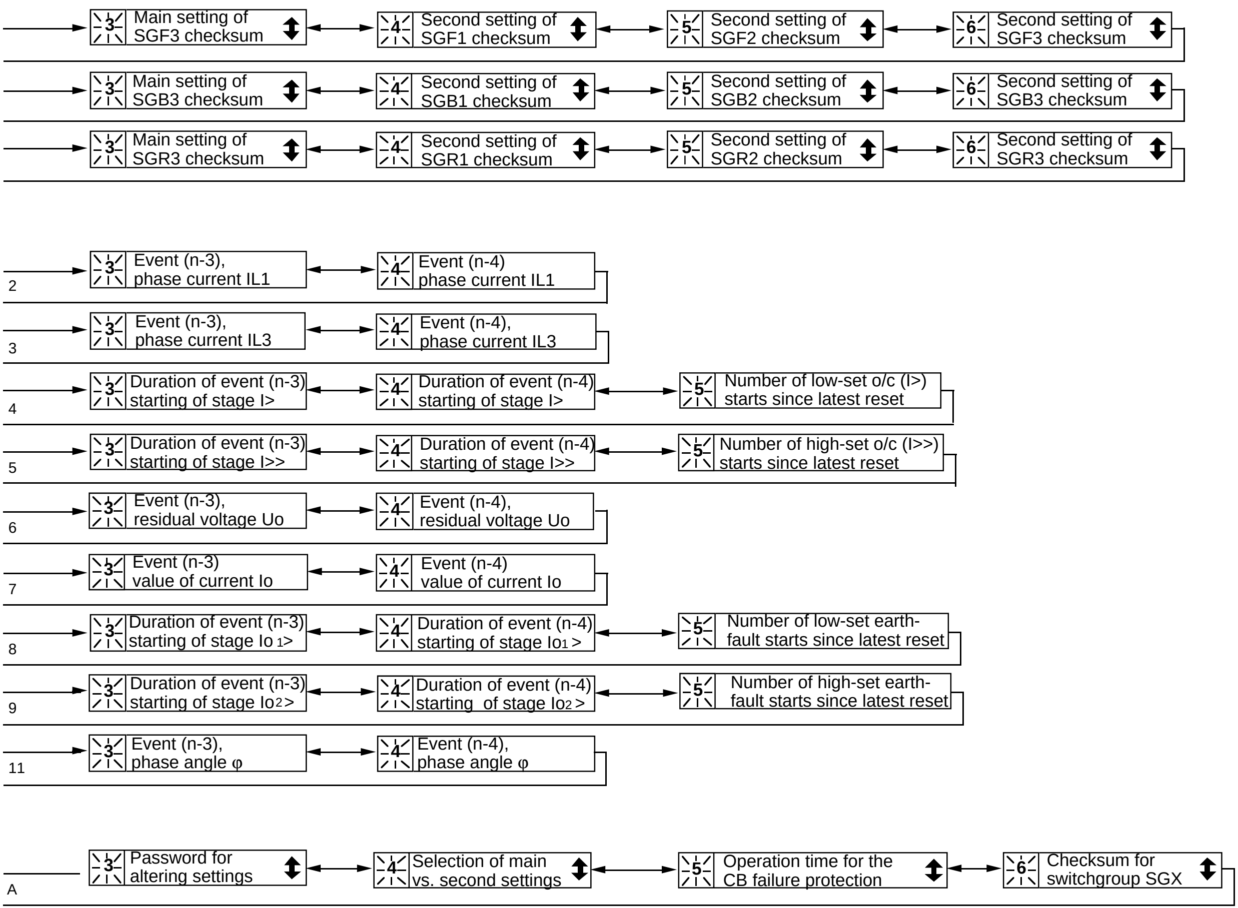


Fig 5. Main menus and submenus of the two-phase overcurrent module SPCJ 4D44.

The measures required for entering a submenu or a setting mode and how to perform the setting and use the TEST mode are described in detail on data sheet "General characteristics of the D-type relay modules". Below a short key to the operations:

Desired step or operation	Push-button	Action
Forward step in main or submenu	STEP	Press > 0.5 s
Rapid scan forward in main menu	STEP	Keep depressed
Reverse step in main or submenu	STEP	Press < 0.5 s
Entering a submenu from a main menu	PROGRAM	Press 1 s
Entering or leaving setting mode	PROGRAM	Press for 5 s
Increasing a value in setting mode	STEP	
Moving the cursor in setting mode	PROGRAM	Press about 1 s
Storing a value in setting mode	STEP & PROGRAM	Press simultaneously
Resetting of memorized values + latched output relays	STEP & PROGRAM	
Resetting of latched output relays	PROGRAM	Note! Display must be off



Time/current characteristics

The operation of the low-set overcurrent stage I> is based on either definite time or inverse time characteristics, as selected in the relay module. The desired characteristic for the overcurrent stage I> is selected with switches 1...3 of switchgroup SGF1.

When an IDMT characteristic has been selected, the operation time of the stage will be a function of the current: the higher the current, the shorter the operation time. The rely module incorporates six different time/current characteristics - four according to BS and IEC and two special characteristics called RI and RXIDG.

BS type characteristic

Four standard characteristics are defined: extremely inverse, very inverse, normal inverse and long time inverse. The characteristics comply with the standards BS 142.1966 and IEC 60255-3 and can generally be expressed as:

$$t\,[s] = \frac{k \times \beta}{(I/I>)^{\alpha} - 1}$$

where:
t = operate time in seconds
k = time multiplier
I = measured phase current
I>= set start current

The relay module incorporates four BS 142 specified characteristics with different degrees of inversity. The degree of inversity is determined by the values of the constants α and β.

Characteristic (IDMT curves)	α	β
Normal inverse	0.02	0.14
Very inverse	1.0	13.5
Extremely inverse	2.0	80.0
Long time inverse	1.0	120.0

According to the standard BS 142.1966 the normal current range is defined as 2...20 times the setting current. Additionally the relay must start at the latest when the measurd current exceeds 1.3 times the set starting value, when the time/current characteristic is normal inverse, very inverse or extremely inverse. When the characteristic is long time inverse, the normal range accordance to the standards is 2...7 times the set starting value and the relay must start when the current exceeds 1.1 times the set starting value.

The following requirements regarding tolerances of the operation time are specified in the standard (E denotes accuracy in per cent, - = not specified):

I/I>	Normal inverse	Very inverse	Extermely inv.	Long time inv.
2	2.22 E	2.34 E	2.44 E	2.34 E
5	1.13 E	1.26 E	1.48 E	1.26 E
7	-	-	-	1.00 E
10	1.01 E	1.01 E	1.02 E	-
20	1.00 E	1.00 E	1.00 E	-

The accuracy of the operation time of the IDMT curves of the low-set overcurrent stage of the relay module SPCJ 4D44 comply with the tolerances of class 5.

Note.
The actual operate time of the relay, presented in the graphs in Fig. 6…9, includes an additional filter and detection time plus the operate time of the trip output relay. When the operate time of the relay is calculated using the mathematical expression above, these additional times of about 30 ms in total have to be added to the time received.

RI-type characteristic

The RI type characteristic is a special characteristic used mainly for timegrading with existing mechanical relays. The characteristic is defined by the following mathematical expression:

t [s] = k/(0.339 - 0.236 x I>/I)

where
t = operate time in seconds
k = time multiplier
I = measured phase current
I> = set start current

RXIDG-type characteristic

The RXIDG characteristic is a special characteristic where a high degree of selectivity is needed also for high-resistance faults. With this characteristic, the protection does not have to be directional and the scheme can operate without pilot communication.

The time/current characteristic can be expressed as:

t [s] = 5.8 - 1.35 x $\log_e$(I/k x I>)

where
t = operate time in seconds
k = time multiplier
I = measured phase current
I> = set start current

Note !
If the setting is higher than 2.5 x I_n, the maximum continuous carry 4 x I_n and the levelling out of the IDMT curves at high current levels must be noted.

CAUTION !
Never use start current settings above 2.5 x I_n at inverse time characteristic, although allowed by the relay.

Note !
The high-current end of any inverse time characteristic is determined by the high-set stage which, when started, inhibits the low-set stage operation. Thus, the trip time is equal to the set operate time t>> for any current higher than I>>. In order to get a trip signal, the stage I>> must also, of course, be linked to a trip output relay.

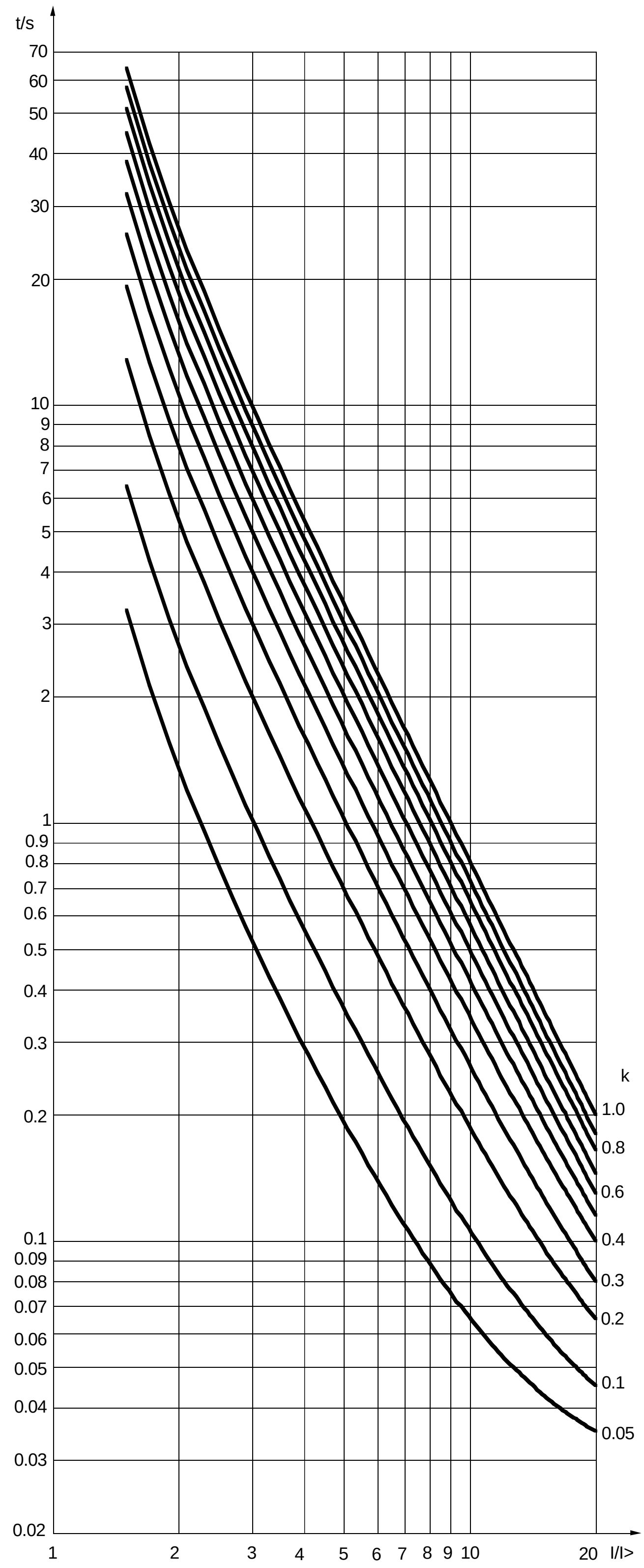


Fig 6. Extremely inverse-time characteristics of the two-phase overcurrent module SPCJ 4D44.

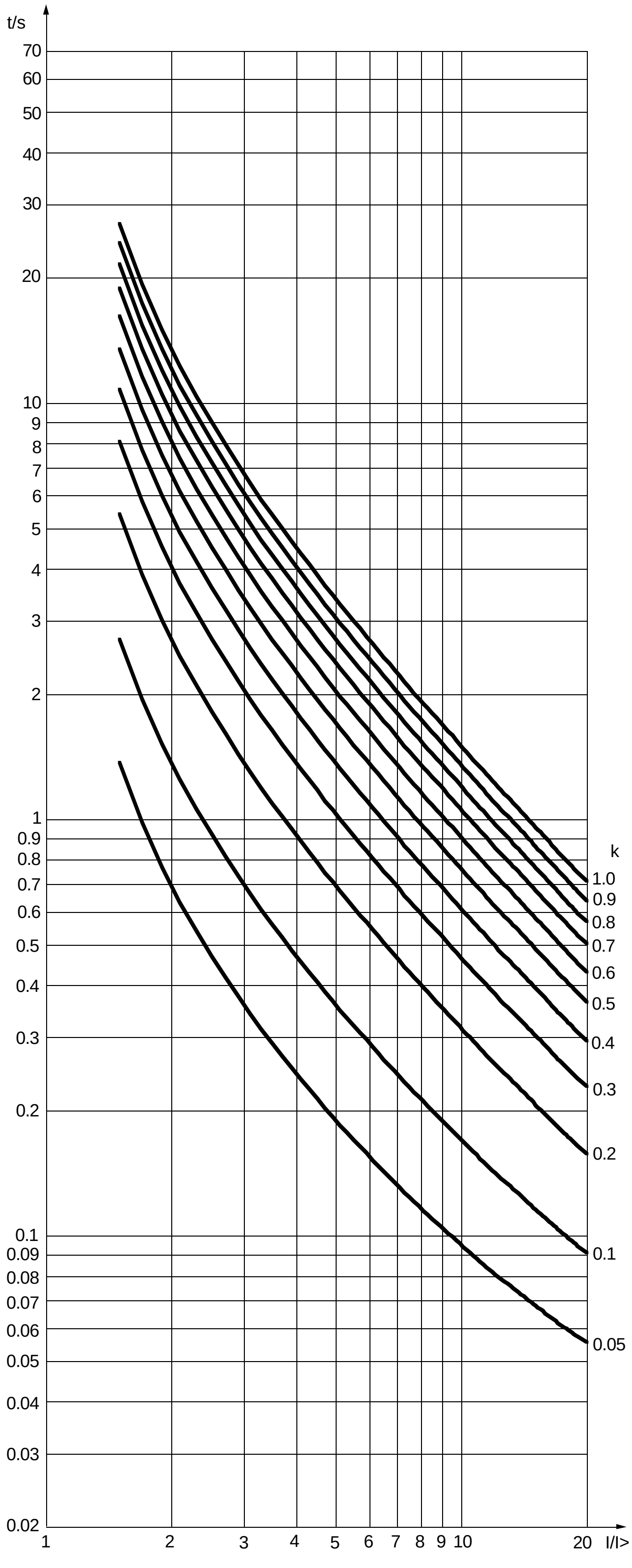


Fig 7. Very inverse-time characteristics of the two-phase overcurrent module SPCJ 4D44.

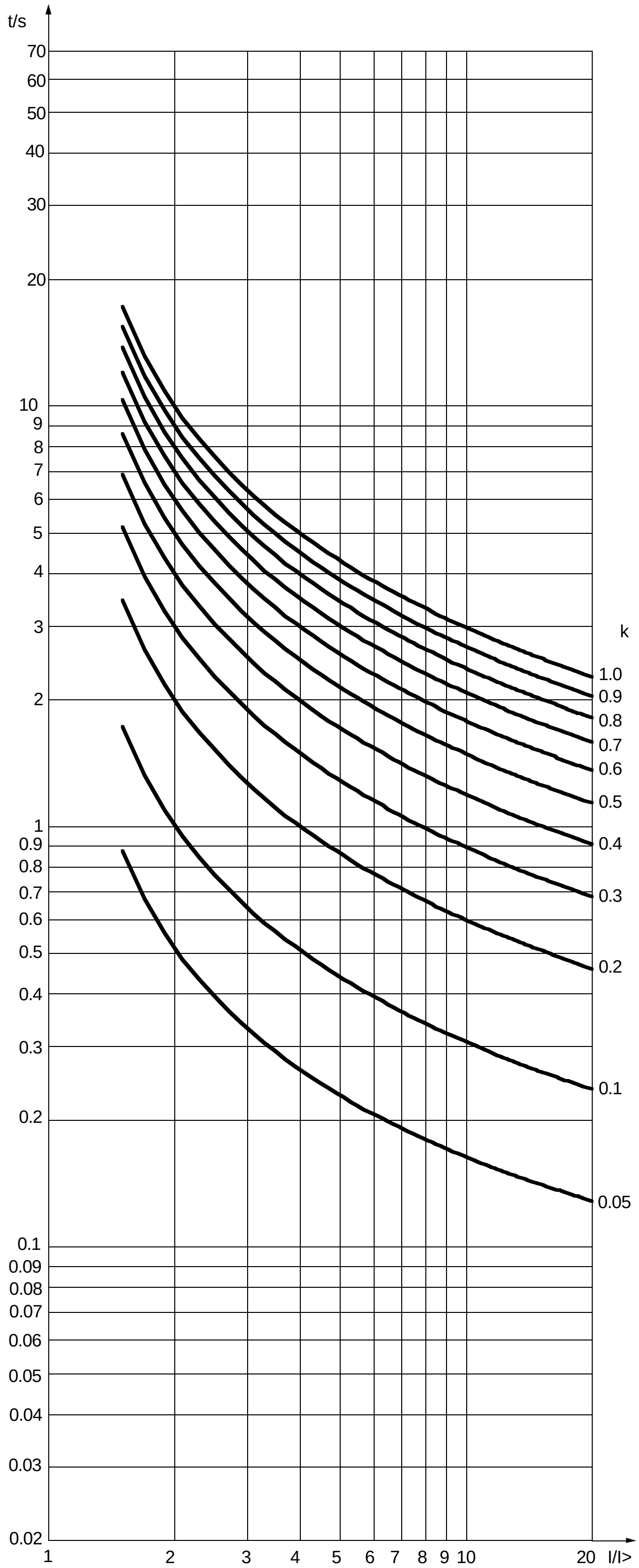


Fig 8. Normal inverse-time characteristics of the two-phase overcurrent module SPCJ 4D44.

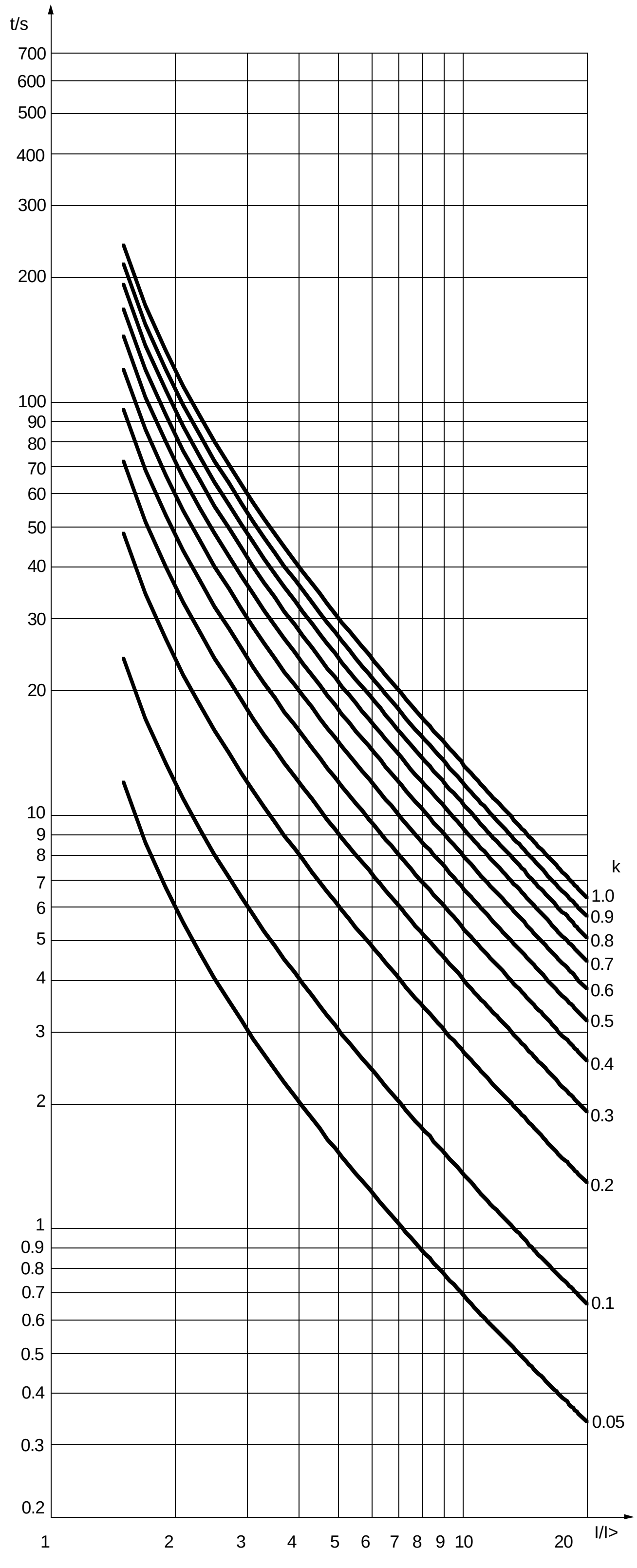


Fig 9. Long-time inverse-time characteristics of the two-phase overcurrent module SPCJ 4D44.

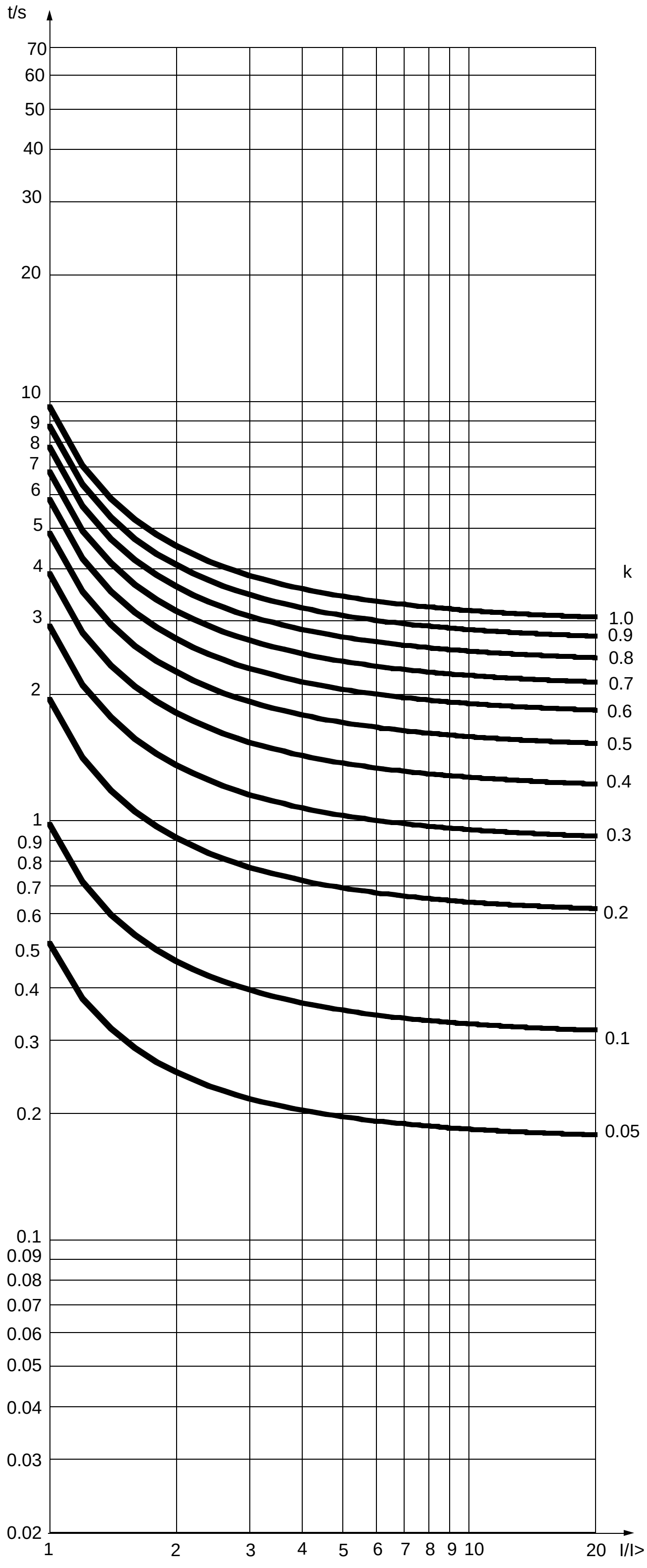


Fig 10. RI-type inverse-time characteristics of the two-phase overcurrent module SPCJ 4D44.

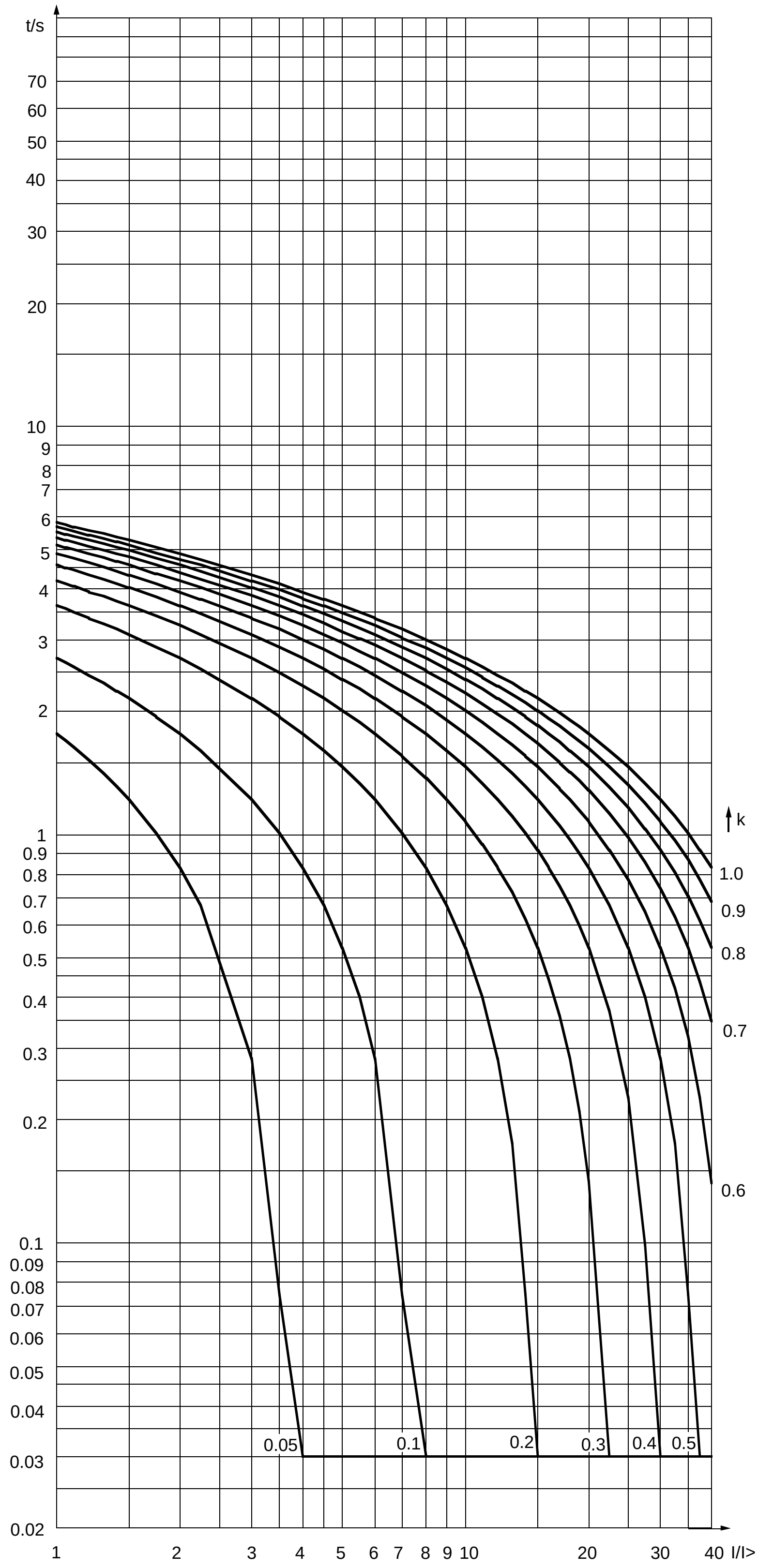


Fig 11. RXIDG-type inverse-time characteristics of the two-phase overcurrent module SPCJ 4D44.

Technical data

Overcurrent unit

Low-set stage I>	
Start current I>	
- at definite time	0.5...5.0 x I_n
- at inverse time	0.5...2.5 x I_n
Start time, typ.	60 ms
Operate time at definite time characteristic	0.05...300 s
Current/time curves at IDMT operation characteristic	Extremely inverse Very inverse Normal inverse Long time inverse RI type inverse RXIDG type inverse
Time multiplier k	0.05...1.00
Reset time, typ.	50 ms
Drop-off/pick-up ratio, typ.	0.96
Operate time accuracy at definite time operation characteristic	±2% of set value or ±25 ms
Operate time accuracy class E at inverse time operation characteristic	5
Operation accuracy	±3% of set value
High-set stage I>>	
Start current I>>	0.5...40.0 x I_n or ∞ , infinite
Start time, typ.	40 ms
Operate time, typ.	0.04...300 s
Reset time, typ.	50 ms
Drop-off/pick-up ratio, typ.	0.96
Operate time accuracy	±2% of set value or ±25 ms
Operation accuracy	±3% of set value

Note!
If the setting is higher than 2.5 x I_n, the maximum continuous carry 4 x I_n and the levelling out of the IDMT curves at high current levels must be noted.

CAUTION !
Never use start current settings above 2.5 x I_n at inverse time characteristic, although allowed by the relay.

Note!
The high-current end of any inverse time characteristic is determined by the high-set stage which, when started, inhibits the low-set stage operation. Thus, the trip time is equal to the set operate time t>> for any current higher than I>>. In order to get a trip signal, the stage I>> must also, of course, be linked to a trip output relay.

Earth-fault unit

Basic angle φb	0°, -30°, - 60° or -90°
Operation sector Δφ	±80°, ±88°. Extended operation sector *)
Operation principle	Phase-angle measuring function. I_0 cosφ function *)
Residual voltage stage U_0>	
Start voltage U_0>	2.0...80.0% U_n
Low-set stage I_{01}>	
Operation direction	Forward or reverse
Start current I_{01}>	1.0...25.0% I_n
Start time, typ.	100 ms
Operate time t_{01}>	0.1...300 s
Reset time, typ.	80 ms
Drop-off/pick-up ratio, typ.	0.96
Operate time accuracy	±2% of set value or ±25 ms
Operation accuracy	±3% of set value + 0.0005 x I_n
High-set earth-fault stage I_{02}>	
Operation direction	Forward or reverse
Operation mode	Directional or non-directional
Start current I_{02}>	2.0...150% I_n or ∞, infinite
Start time	100 ms or 750 ms
Operate time t_{02}>	100 ms or 750 ms. Extended operate time *)
Reset time	
-during start (SGF3/6=0), typ.	100 ms
-during start (SGF3/6=1), typ.	500 ms
-after tripping, typ.	100 ms
Internal reset time of intermittent operation	500 ms
Drop-off/pick-up ratio, typ.	0.96
Operate time accuracy	±2% of set value or ±25 ms **)
Operation accuracy	±3% of set value +0.0005 x I_n

*) See chapter "Technical data affected by versions SW 089 E, F", page 46.
**) When the detection of intermittent earth fault function has been selected for the I_{02}> stage (SGF3/6=1) and the stage operates on intermittent earth faults with disruptive discharge pulses exceeding 100 ms, the operate time can be extended with that same time (max. 500 ms).

Event codes

When the combined two-phase overcurrent and directional earth-fault module SPCJ 4D44 is connected to a data communicator over the SPA bus, the module will generate event markings which can be printed out, for instance, on a printer or transmitted to higher system levels via the serial bus. The events are printed out in the format: time, text and event code. The event text is written by the user.

An event to be communicated, is marked with the multiplier 1. If the event is to be excluded the multiplier is 0. The event mask is formed by the sum of the weighting coefficients of all the events to be communicated.

The event masks V155 and V156 may have a value within the range 0...255 while the event mask V157 may take a value within the range 0...1023. The parameters of the event masks are presented in the tables below. The default values of the event masks are calculated according to these tables.

The event codes E50...E54 and the events represented by these cannot be excluded from the event reporting. The event codes E52...E54 are generated by the data communicator used, e.g. SACO 100M, SRIO 1000M, etc.

Detailed information about the serial communication over the SPA bus is given in the document "SPA bus communication protocol", Document No. 34 SPACOM 2EN1.

Event mask	Code	Setting range	Default value
V155	E1…E8	0…255	85
V156	E9…E16	0…255	85
V157	E17…E26	0…1023	768

Code	Event	Weighting coefficient	Default setting
E1	Starting of stage I>	1	1
E2	Starting of stage I> reset	2	0
E3	Operation of stage I>	4	1
E4	Operation of stage I> reset	8	0
E5	Starting of stage I>>	16	1
E6	Starting of stage I>> reset	32	0
E7	Operation of stage I>>	64	1
E8	Operation of stage I>> reset	128	0
	Default setting for event mask V155		85

E9	Starting of stage $I_{01}>$	1	1
E10	Starting of stage $I_{01}>$ reset	2	0
E11	Operation of stage $I_{01}>$	4	1
E12	Operation of stage $I_{01}>$ reset	8	0
E13	Starting of stage $U_0>$	16	1
E14	Starting of stage $U_0>$ reset	32	0
E15	Operation of stage $I_{02}>$	64	1
E16	Operation of stage $I_{02}>$ reset	128	0
	Default setting for event mask V156		85

E17	Output signal TS1 activated	1	0
E18	Output signal TS1 reset	2	0
E19	Output signal SS1 activated	4	0
E20	Output signal SS1 reset	8	0
E21	Output signal SS2 activated	16	0
E22	Output signal SS2 reset	32	0
E23	Output signal SS3 activated	64	0
E24	Output signal SS3 reset	128	0
E25	Output signal TS2 activated	256	1
E26	Output signal TS2 reset	512	1
	Default setting for event mask V157		768

E50	Restart of module	*	-
E51	Overflow of event register	*	-
E52	Temporary disturbance in data communication	*	-
E53	No response from the relay module over the data communication	*	-
E54	The relay module responds again over the data communication	*	-

0 Not included in the event reporting
1 included in the event reporting
* No code number
- Cannot be set

Data to be transferred over the serial bus

In addition to the event data transfer the SPA bus allows reading of all input data (I-data), output data (O-data), setting values (S-data), information recorded in the memory (V-data), and some other data of the module. Further, part of the data can be altered by commands given over the SPA bus.

When setting values are altered via the MMI on the front panel or via the serial bus, the module checks that the entered parameter values are within the permitted setting range. The relay module refuses to accept a too high or a too low setting value, but keeps the old setting value unchanged.

Altering parameter values via the serial bus usually requires the use of a password. The password is a number within the range 1...999. The default password is 1.

The password is opened by writing the password number to parameter V160 and closed by writing the password number to parameter V161. The password is also closed on loss of auxiliary supply to the relay module.

The password can be changed via the serial bus or via the MMI of the module. When the password is to be changed via the serial bus, the password must be opened first. The new password is written to parameter V161. The change of the password via the MMI of the module is carried out in register A, subregister 3, in which case the new password is written over the old one.

If an incorrect password is given seven times in a row via the serial bus, the password is automatically set to zero and after this it cannot be opened via the serial bus. Now the password can be opened only via the MMI of the module.

All the data are available in channel 0.

MMI = Man-Machine Interface
R = data to be read from the unit
W = data to be written to the unit
(P) = writing enabled by a password

Data	Code	Data direct.	Values
INPUTS			
Measured current on phase L1	I1	R	0...63 x I_n
Measured current on phase L3	I2	R	0...63 x I_n
Measured residual voltage U_0	I3	R	0...106% U_n
Measured neutral current I_0	I4	R	0...210% I_n
Phase angle φ between basic angle φ_b and I_0	I5	R	-180°…0°...180°, 999 = signal too low to be measured
Blocking or control signal BS1	I6	R	0 = no blocking 1 = BS1 signal active
Blocking or control signal BS2	I7	R	0 = no blocking 1 = BS2 signal active
Blocking or control signal RRES	I8	R	0 = no blocking 1 = RRES signal active

Data	Code	Data direct.	Values
OUTPUTS			
Starting of stage I>	O1	R	0 = I> stage not started 1 = I> stage started
Tripping of stage I>	O2	R	0 = I> stage not tripped 1 = I> stage tripped
Starting of stage I>>	O3	R	0 = I>> stage not started 1 = I>> stage started
Tripping of stage I>>	O4	R	0 = I>> stage not tripped 1 = I>> stage tripped
Starting of stage I_{01}>	O5	R	0 = I_{01}> stage not started 1 = I_{01}> stage started
Tripping of stage I_{01}>	O6	R	0 = I_{01}> stage not tripped 1 = I_{01}> stage tripped
Starting of stage U_0>	O7	R	0 = U_0> stage not started 1 = U_0> stage started
Tripping of stage I_{02}>	O8	R	0 = I_{02}> stage not tripped 1 = I_{02}> stage tripped
Signal TS1	O9	R,W(P)	0 = signal not active 1 = signal active
Signal SS1	O10	R,W(P)	0 = signal not active 1 = signal active
Signal SS2	O11	R,W(P)	0 = signal not active 1 = signal active
Signal SS3	O12	R,W(P)	0 = signal not active 1 = signal active
Signal TS2	O13	R,W(P)	0 = signal not active 1 = signal active
Output relays	O41	R,W(P)	0 = not operated 1 = operated
Memorized starting of stage I>	O21	R	0 = signal not active 1 = signal active
Memorized operation of stage I>	O22	R	0 = signal not active 1 = signal active
Memorized starting of stage I>>	O23	R	0 = signal not active 1 = signal active
Memorized operation of stage I>>	O24	R	0 = signal not active 1 = signal active
Memorized starting of stage I_{01}>	O25	R	0 = signal not active 1 = signal active
Memorized operation of stage I_{01}>	O26	R	0 = signal not active 1 = signal active
Memorized starting of stage U_0>	O27	R	0 = signal not active 1 = signal active
Memorized operation of stage I_{02}>	O28	R	0 = signal not active 1 = signal active
Memorized output signal TS1	O29	R	0 = signal not active 1 = signal active
Memorized output signal SS1	O30	R	0 = signal not active 1 = signal active
Memorized output signal SS2	O31	R	0 = signal not active 1 = signal active
Memorized output signal SS3	O32	R	0 = signal not active 1 = signal active
Memorized output signal TS2	O33	R	0 = signal not active 1 = signal active

Data	Code	Data direct.	Values
PRESENT SETTING VALUES			
Ruling starting value of stage I>	S1	R	0.5...5.0 x I_n
Ruling operating time for stage I>	S2	R	0.05...300 s
Ruling starting value for stage I>>	S3	R	0.5...40 x I_n 999 = not in use
Ruling operating time for stage I>>	S4	R	0.04...300 s
Ruling starting value for stage U_0>	S5	R	2.0...80.0% U_n
Ruling starting value for stage I_0>	S6	R	1...25.0% I_n
Ruling operating time for stage I_{01}>	S7	R	0.1...300 s
Ruling starting value for stage I_{02}>	S8	R	2.0...150% I_n 999 = not in use
Ruling checksum of switchgroup SGF1	S9	R	0...255
Ruling checksum of switchgroup SGF2	S10	R	0...255
Ruling checksum of switchgroup SGF3	S11	R	0...255
Ruling checksum of switchgroup SGB1	S12	R	0...255
Ruling checksum of switchgroup SGB2	S13	R	0...255
Ruling checksum of switchgroup SGB3	S14	R	0...255
Ruling checksum of switchgroup SGR1	S15	R	0...255
Ruling checksum of switchgroup SGR2	S16	R	0...255
Ruling checksum of switchgroup SGR3	S17	R	0...255
MAIN SETTING VALUES			
Main starting value for stage I>	S21	R,W(P)	0.5...5.0 x I_n
Main operating time for stage I>	S22	R,W(P)	0.05...300 s
Main starting value for stage I>>	S23	R,W(P)	0.5...40 x I_n
Main operating time for stage I>>	S24	R,W(P)	0.04...300 s
Main starting value for stage U_0>	S25	R,W(P)	2.0...80.0% U_n
Main starting value for stage I_0>	S26	R,W(P)	1...25.0% I_n
Main operating time for stage I_{01}>	S27	R,W(P)	0.1...300 s
Main starting value for stage I_{02}	S28	R,W(P)	2.0...150% I_n
Main checksum of switchgroup SGF1	S29	R,W(P)	0...255
Main checksum of switchgroup SGF2	S30	R,W(P)	0...255
Main checksum of switchgroup SGF3	S31	R,W(P)	0...255
Main checksum of switchgroup SGB1	S32	R,W(P)	0...255
Main checksum of switchgroup SGB2	S33	R,W(P)	0...255
Main checksum of switchgroup SGB3	S34	R,W(P)	0...255
Main checksum of switchgroup SGR1	S35	R,W(P)	0...255
Main checksum of switchgroup SGR2	S36	R,W(P)	0...255
Main checksum of switchgroup SGR3	S37	R,W(P)	0...255
Operation time for circuit breaker failure protection	S61	R,W(P)	0.1...1.0 s

Data	Code	Data direct.	Values
SECOND SETTING VALUES			
Second starting value for stage I>	S41	R,W(P)	0.5...5.0 x I_n
Second operating time for stage I>	S42	R,W(P)	0.05...300 s
Second starting value for stage I>>	S43	R,W(P)	0.5...40 x I_n
Second operating time for stage I>>	S44	R,W(P)	0.04...300 s
Second starting value for stage U_0>	S45	R,W(P)	2.0...80.0% U_n
Second starting value for stage I_{01}>	S46	R,W(P)	1...25.0% I_n
Second operating time for stage I_{01}>	S47	R,W(P)	0.1...300 s
Second starting value for stage I_{02}>	S48	R,W(P)	2.0...150% I_n
Second checksum of switchgroup SGF1	S49	R,W(P)	0...255
Second checksum of switchgroup SGF2	S50	R,W(P)	0...255
Second checksum of switchgroup SGF3	S51	R,W(P)	0...255
Second checksum of switchgroup SGB1	S52	R,W(P)	0...255
Second checksum of switchgroup SGB2	S53	R,W(P)	0...255
Second checksum of switchgroup SGB3	S54	R,W(P)	0...255
Second checksum of switchgroup SGR1	S55	R,W(P)	0...255
Second checksum of switchgroup SGR2	S56	R,W(P)	0...255
Second checksum of switchgroup SGR3	S57	R,W(P)	0...255
Operation time for circuit breaker failure protection	S61	R,W(P)	0.1...1.0 s
RECORDED PARAMETERS			
Current on phase L1 at starting or operation	V11…V51	R	0...63 x I_n
Current on phase L3 at starting or operation	V12…V52	R	0...63 x I_n
Residual voltage U_0 at starting or operation	V13…V53	R	0...106% U_n
Neutral current I_0 at starting or operation	V14…V54	R	0...210% I_n
Duration of the latest starting situation of stage I>	V15…V55	R	0...100 %
Duration of the latest starting situation of stage I>>	V16…V56	R	0...100 %
Duration of the latest starting situation of stage I_{01}>	V17…V57	R	0...100 %
Duration of the latest starting situation of stage I_{02}>	V18…V58	R	0...100 %
Phase angle φ between basic angle $φ_b$ and I_0	V19...V59	R	-180°...0°...180°, 999 = signal too low to be measured
Maximum demand current for 15 min.	V1	R	0...2.5 x I_n
Number of startings of stage I>	V2	R	0...255
Number of startings of stage I>>	V3	R	0...255
Number of startings of stage I_{01}>	V4	R	0...255
Number of startings of stage I_{02}>	V5	R	0...255
Phase condition during trip	V6	R	1 = U_0>, 2 = I>(L3) 4 = I>(L1), 8 = I_{01}> 16 = U_0>>, 32 = I>>(L3) 64 = I>>(L1) 128= I_{02}>
Operation indicator	V7	R	0...9
Highest maximum demand current 15 min value	V8	R	0...2.55 x I_n

Data	Code	Data direct.	Values
CONTROL PARAMETERS			
Resetting of output relays at self-holding	V101	W	1 = reset
Resetting of output relays and registers	V102	W	1 = reset
Remote control of settings	V150	R,W	0 = main settings activated 1 = second settings activated
Switchgroup SGX	V152	R,W(P)	0...63
Event mask word for I> and I>>stage events	V155	R,W	0...255, see section event codes
Event mask word for U_0>, I_{01} and I_{02}> stage events	V156	R,W	0...255, see section event codes
Event mask word for output signal events	V157	R,W	0...1023, see section event codes
Opening of password for remote settings	V160	W	1...999
Changing or closing of password for remote settings	V161	W(P)	0...999
Activating of self-supervision output	V165	W	1 = self-supervision output is activated and IRF led turned on 0 = off
Formatting of EEPROM	V167	W(P)	2 = formatting
Internal error code	V169	R	0...255
Data communication address of the module	V200	R,W	1...254
Data transfer rate	V201	R,W	4800 or 9600 Bd (R) 4.8 or 9.6 kBd (W)
Programme version number	V205	R	089_
Event register reading	L	R	time, channel number and event code
Re-reading of event register	B	R	time, channel and event code
Type designation of the module	F	R	SPCJ 4D44
Reading of module status data	C	R	0 = normal state 1 = module been subject to automatic reset 2 = overflow of event register 3 = events 1 and 2 together
Resetting of module state data	C	W	0 = resetting
Time reading and setting	T	R,W	0.000...59.999 s

The event register can be read with the L command only once. Should a fault occur e.g. in the data transfer, the contents of the event register read with an L command may be re-read with a B command. When required, the B command can be repeated. Generally, the control data communicator reads the event data and forwards them to the output device . Under normal conditions the event register of the relay module is empty. In the same way the data communicator resets abnormal status data, thus this data is normally zero.

The setting values S1...S17 are the setting values used by the protection programs. These values are set either as the main settings and switchgroup checksums S21...S37 or as the corresponding second settings S41...S57. All the settings can be read or written. A condition for writing is that the remote set password has been opened.

When changing settings, the relay module checks that the variables given are within the ranges specified in the technical data of the relay module. If a value beyond the limits is given to the relay module, either manually or by remote setting, the module will not store the value but will keep the previous setting value.

Fault codes

Once the internal self-supervision system has detected a permanent relay fault the red IRF indicator is lit and the output relay of the self-supervision system operates. Further, in most fault situations an autodiagnostic fault code is shown on the display. The fault code is composed of a red number 1 and a green code number which indicates the fault type. When a fault code appears on the display, the code number should be recorded and submitted to the authorized repair shop when overhaul is ordered. Below a list of some of the autodiagnostic fault codes that might appear on the display of the relay module SPCJ 4D44:

Fault code	Type of error in module
4	Trip relay path broken or output relay card missing
30	Faulty program memory (ROM)
50	Faulty work memory (RAM)
51	Parameter memory (EEPROM) block 1 faulty
52	Parameter memory (EEPROM) block 2 faulty
53	Parameter memory (EEPROM) block 1 and block 2 faulty
54	Parameter memory (EEPROM) block 1 and block 2 faulty with different checksums
56	Parameter memory (EEPROM) key faulty. Format by writing a "2" to variable V167
195	Too low a value in reference channel with multiplier 1
131	Too low a value in reference channel with multiplier 5
67	Too low a value in reference channel with multiplier 25
203	Too high a value in reference channel with multiplier 1
139	Too high a value in reference channel with multiplier 5
75	Too high a value in reference channel with multiplier 25
252	Faulty hardware filter on E/F channel
253	No interruptions from the A/D converter

Appendix 1

General

Appendix 1 describes the changes made to the program versions SW 089 C and SW 089 D of the combined phase overcurrent and directional earth-fault module SPCJ 4D44. An optional function for the detection of intermittent earth faults has been added to the earth-fault stage I_{02}>.

Intermittent earth faults

A typical intermittent earth fault includes one or several earth fault current peaks during one distruptive discharge. The peak current is very high and the time between the disruptive discharges may exceed 200 ms.

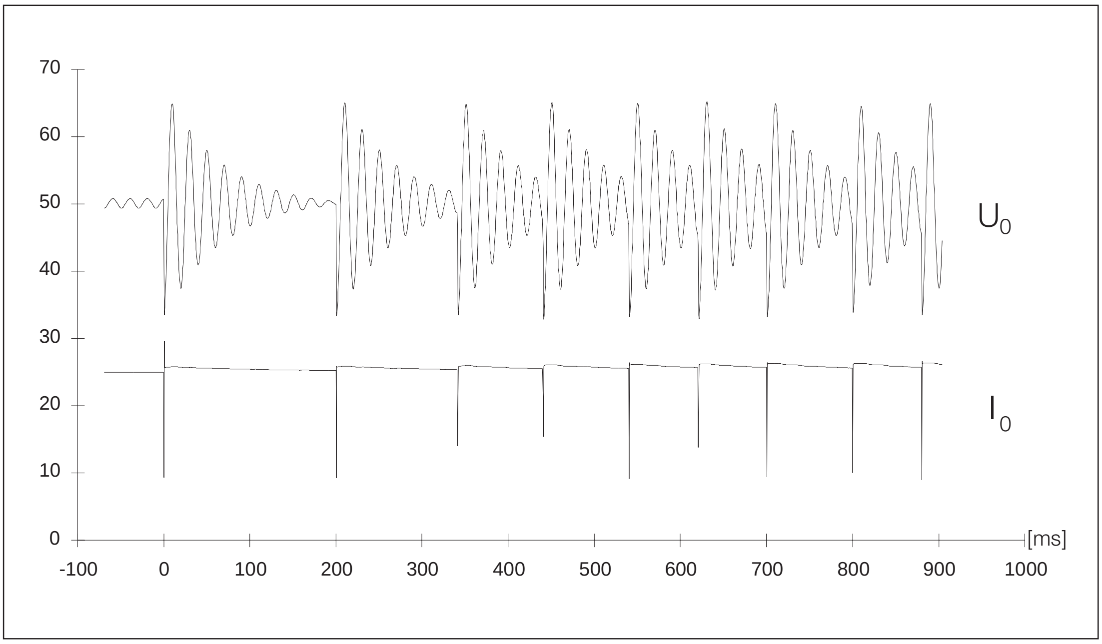


Figure 1. An intermittent earth fault measured in an underground cable.

Description of functions added to program versions SW 089 C and SW 089 D

The I_{02}> stage can be selected to operate either as a normal earth-fault stage or as an intermittent earth-fault stage. When SGF3/6 = 0, the stage operates as a normal earth-fault stage. When SGF3/6 = 1, the stage is able to detect intermittent earth faults.

Description of function of stages I_{01}> and I_{02}>, when SGF3/6=1

The directional earth-fault stage I_{01}> operates on resistive earth faults and intermittent earth faults with disruptive discharge pulses of up to 100 ms. The I_{02}> stage is blocked when the I_{01}> stage is activated.

At intermittent earth faults with disruptive discharge pulses between 100 ms and 500 ms, i.e. outside the operating range of the I_{01}> stage, the blocking of stage I_{02}> will be eliminated. Then the I_{02}> stage is activated, delivering a trip signal in 750 ms, if U_0, I_0 and the phase angle fulfil the start criteria.

Appendix 2

General

Appendix 2 describes the changes made to the earth-fault stages I_{01}> or I_{02}> of the combined phase overcurrent and directional earth-fault module SPCJ 4D44 with program version SW 089 F and later. These changes have been made to improve the functions of the faulted line and healthy lines.

Extending the negative part of the operation sector of the earth-fault stages

When the I_{02}> stage has been programmed for detecting intermittent earth faults (SGF3/6=1), the negative operation sector will automatically be extended to -120° or -170°, as selected with switch SGF3/7. When the switch is in position 0, the operation area will be -120°, and when the switch is in position 1, it will be -170°. The extended operation area applies to both directional earth-fault stages. As the operation sector of the earth-fault stages can be set to -120° or -170°, the function of the earth-fault relay of the faulted line can be considerably improved at an intermittent earth fault.

Reducing the positive part of the operation sector of the I_{02}> stage

When the I_{02}> stage has been programmed for detecting intermittent earth faults, the positive operation sector can be set at +60°, +68°, +70°, +78°, +80° or +88° using the programming switches SGX/5 and SGX/6. The positive operation sector can only be reduced for the I_{02}> stage. This function can be selected in special situations, where the phase angle measured for the healthy line may turn towards the operation area.

Selectable operate times, t_{02}> for stage I_{02}>

Four optional operate times have been added to the I_{02}> stage. The operate times are selected with the switches SGX/1 and SGX/2.

- When SGF3/6=0, the operate times 0.10 s, 1.50 s, 2.00 s and 2.50 s will be available
- When SGF3/6=1, the operate times 0.75 s, 1.50 s, 2.00 s and 2.50 s will be available

Selectable $I_0\cos\varphi$ function for the earth-fault stages

An $I_0\cos\varphi$ function, selectable with the programming switches SGX/3 and SGX/4, has been added to the directional earth-fault stage. Under normal conditions, the angle measuring principle is used, but, when required, the $I_0\cos\varphi$ principle can be used to obtain selectivity with other $I_0\cos\varphi$ measuring relays and to improve the function of healthy lines in an earth-fault situation.

Programming switches SGF3/7 and SGX/1...6

The programming switch SGF3/7 has been assigned a function. In addition, the module has been provided with a new switchgroup SGX, which can be programmed either from the front panel of the module, via submenu 6 of register A, or over the serial SPA communication, parameter V152.

Switch	Function	Default setting
SGF3/7	Selection of the extended negative operation sector for the directional earth-fault stages. The extended negative operation sector can only be selected when the I_{02}> stage has been programmed to detect intermittent earth faults, i.e. SGF3/6 = 1. *N.B. The extended operation sector -120° or -170° can only be selected at phase-angle measuring function or at $I_0\cos\varphi$ function on the positive sector. See Fig. 1 and 2, page 42, 43* When SGF3/7 = 0, the negative operation sector is extended to -120° When SGF3/7 = 1, the negative operation sector is extended to -170°	0 0
SGF3/8	Not in use	0

Switchgroup SGX is used for selecting the following functions.

<table>
<tr><th>Switch</th><th>Function</th><th>Default setting</th></tr>
<tr><td>SGX/1
SGX/2</td><td>Selection of operate time t_{02}> for stage I_{02}>
N.B! The switch SGF3/6 also affects the operate time t_{02}> as follows:
<table>
<tr><th>SGX/1</th><th>SGX/2</th><th>I_{02}> normal E/F (SGF3/6=0)</th><th>I_{02}> Interm. E/F (SGF3/6=1)</th></tr>
<tr><td>0</td><td>0</td><td>0.10 s</td><td>0.75 s</td></tr>
<tr><td>1</td><td>0</td><td>1.50 s</td><td>1.50 s</td></tr>
<tr><td>0</td><td>1</td><td>2.00 s</td><td>2.00 s</td></tr>
<tr><td>1</td><td>1</td><td>2.50 s</td><td>2.50 s</td></tr>
</table>
</td><td>0</td></tr>
<tr><td>SGX/3
SGX/4</td><td>Selection of operation principle for the directional earth-fault stages I_{01}> and I_{02}>
<table>
<tr><th>SGX/3</th><th>SGX/4</th><th>Operation principle</th></tr>
<tr><td>0</td><td>0</td><td>Phase-angle measuring function on the positive and the negative sector</td></tr>
<tr><td>1</td><td>0</td><td>$I_0 \cos\varphi$ function for the positive sector and phase-angle measuring function for the negative sector.</td></tr>
<tr><td>0</td><td>1</td><td>$I_0 \cos\varphi$ function for both the negative and the positive sector[1)]</td></tr>
<tr><td>1</td><td>1</td><td>$I_0 \cos\varphi$ function for both the negative and the positive sector[1)]</td></tr>
</table>
[1)] The operation sector $\Delta\varphi$ will automatically be symmetrical, when $I_0 \cos\varphi$ function has been selected both for the negative sector and the positive sector, see Fig. 3, page 44.
</td><td>0</td></tr>
<tr><td>SGX/5
SGX/6</td><td>Selection of positive operation sector for the directional earth-fault stage I_{02}>
N.B! The positive operation sector can be selected only when the I_{02}> stage has been programmed to detect intermittent earth faults (SGF3/6=1)
<table>
<tr><th>SGX/5</th><th>SGX/6</th><th>Negative operation sector - 120° (SGF3/7=0)</th><th>Negative operation sector - 170° (SGF3/7=1)</th></tr>
<tr><td>0</td><td>0</td><td>-120°...0°...+80° [2)]</td><td>-170°...0°...+80° [2)]</td></tr>
<tr><td>1</td><td>0</td><td>-120°...0°...+70° [2)]</td><td>-170°...0°...+70° [2)]</td></tr>
<tr><td>0</td><td>1</td><td>-120°...0°...+60° [2)]</td><td>-170°...0°...+60° [2)]</td></tr>
<tr><td>1</td><td>1</td><td>-120°...0°...+60° [2)]</td><td>-170°...0°...+60° [2)]</td></tr>
</table>
[2)] If SGF3/5=1, 8° will be added to the positive operation sector.
</td><td>0</td></tr>
<tr><td>SGX/7
SGX/8</td><td>Not in use</td><td>0</td></tr>
</table>

Configuration alternatives for the directional earth-fault stages

1. Earth-fault stages with phase-angle measuring function

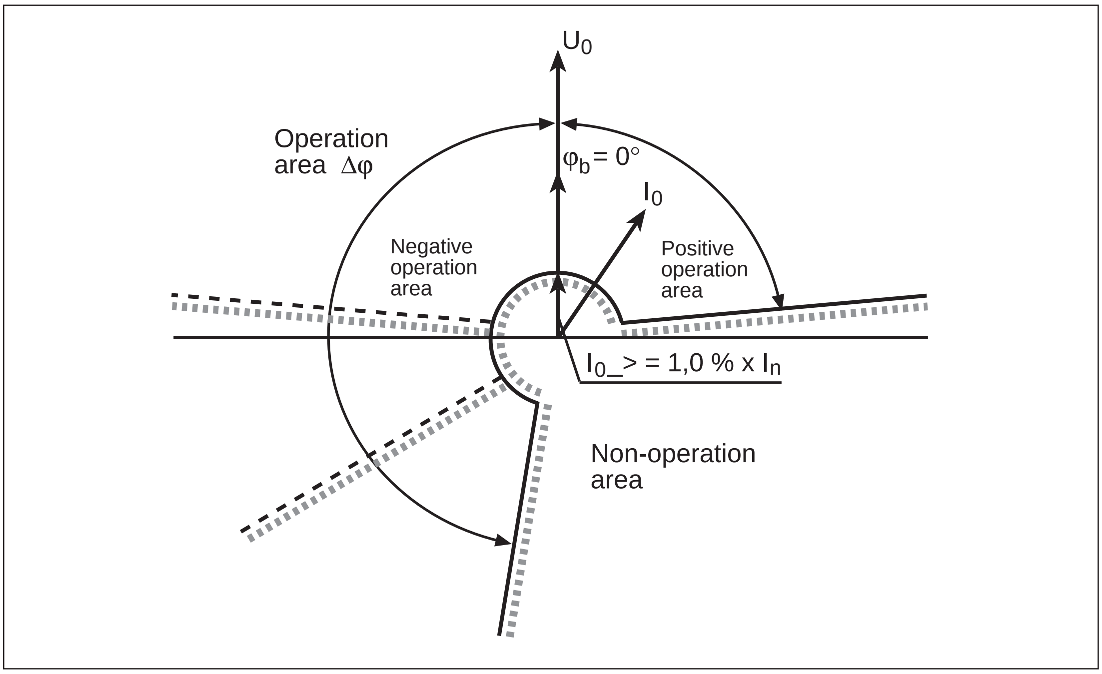


Fig.1. Example of three operation areas -80°...0°...+80°, -120°...0°...+80° and -170°...0°...+80°, when the basic angle φ_b = 0°.

Table 1: Operation areas to be selected with the SGF_ and SGX switches at phase-angle measuring function

Switch			Earth-fault stages with phase-angle measuring function SGX/3 = 0 & SGX/4 = 0		
			Earth-fault stages set to operate on normal earth faults, (SGF3/6=0)	I_{02}> stage set to operate on intermittent earth faults, (SGF3/6 = 1)	
Stage I_{01}>					
SGF3/5			SGF3/6 = 0	SGF3/6 = 1 & SGF3/7 = 0	SGF3/6 = 1 & SGF3/7 = 1
0			-80°...0°...+80°	-120°...0°...+80°	-170°...0°...+80°
1			-88°...0°...+88°	-120°...0°...+88°	-170°...0°...+88°
Stage I_{02}>					
SGF3/5	SGX/5	SGX/6	SGF3/6 = 0	SGF3/6 = 1 & SGF3/7 = 0	SGF3/6 = 1 & SGF3/7 = 1
0	0	0	-80°...0°...+80°	-120°...0°...+80°	-170°...0°...+80°
0	1	0	-80°...0°...+80°	-120°...0°...+70°	-170°...0°...+70°
0	0	1	-80°...0°...+80°	-120°...0°...+60°	-170°...0°...+60°
1	0	0	-88°...0°...+88°	-120°...0°...+88°	-170°...0°...+88°
1	1	0	-88°...0°...+88°	-120°...0°...+78°	-170°...0°...+78°
1	0	1	-88°...0°...+88°	-120°...0°...+68°	-170°...0°...+68°

2. Earth-fault stages with $I_0\cos\varphi$ function on the positive sector and phase-angle measuring function on the negative sector

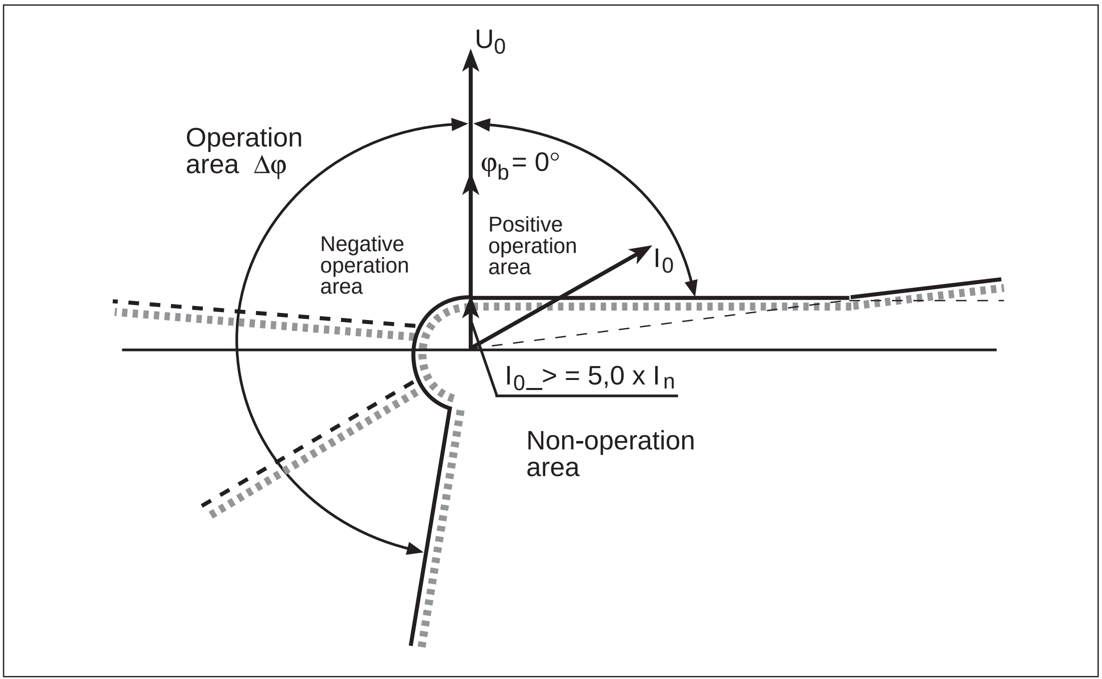


Fig.2. Example of three operation areas, -80°...0°...+80° & $I_0\cos\varphi$, -120°...0°...+80° & $I_0\cos\varphi$ and -170°...0°...+80° & $I_0\cos\varphi$, when the basic angle φ_b = 0°.

Table 2: Operation areas to be selected with the SGF_ and SGX switches at $I_0\cos\varphi$ function on the positive sector and phase-angle measuring function on the negative sector

<table>
<tr><td colspan="3" rowspan="2">Switch</td><td colspan="3">Earth-fault stages with $I_0\cos\varphi$ function on the positive sector and phase-angle measuring function on the negative sector.
SGX/3 = 1 & SGX/4 = 0</td></tr>
<tr><td>Earth-fault stages set to operate on normal earth faults, SGF3/6 = 0</td><td colspan="2">I_{02}> stage set to operate on intermittent earth faults, SGF3/6 = 1</td></tr>
<tr><td colspan="6">Stage I_{01}></td></tr>
<tr><td colspan="3">SGF3/5</td><td>SGF3/6 = 0</td><td>SGF3/6 = 1 &
SGF3/7 = 0</td><td>SGF3/6 = 1 &
SGF3/7 = 1</td></tr>
<tr><td colspan="3">0
1</td><td>-80°...0°...+80° & $I_0\cos\varphi$
-88°...0°...+88° & $I_0\cos\varphi$</td><td>-120°...0°...+80° & $I_0\cos\varphi$
-120°...0°...+88° & $I_0\cos\varphi$</td><td>-170°...0°...+80° & $I_0\cos\varphi$
-170°...0°...+88° & $I_0\cos\varphi$</td></tr>
<tr><td colspan="6">Stage I_{02}></td></tr>
<tr><td>SGF3/5</td><td>SGX/5</td><td>SGX/6</td><td>SGF3/6 = 0</td><td>SGF3/6 = 1 &
SGF3/7 = 0</td><td>SGF3/6 = 1 &
SGF3/7 = 1</td></tr>
<tr><td>0
0
0
1
1
1</td><td>0
1
0
0
1
0</td><td>0
0
1
0
0
1</td><td>-80°...0°...+80° & $I_0\cos\varphi$
-80°...0º...+80° & $I_0\cos\varphi$
-80°...0º...+80° & $I_0\cos\varphi$
-88°...0º...+88° & $I_0\cos\varphi$
-88°...0°...+88° & $I_0\cos\varphi$
-88°...0°...+88° & $I_0\cos\varphi$</td><td>-120°...0°...+80° & $I_0\cos\varphi$
-120°...0°...+70° & $I_0\cos\varphi$
-120°...0°...+60° & $I_0\cos\varphi$
-120°...0°...+88° & $I_0\cos\varphi$
-120°...0°...+78° & $I_0\cos\varphi$
-120°...0°...+68° & $I_0\cos\varphi$</td><td>-170°...0°...+80° & $I_0\cos\varphi$
-170°...0°...+70° & $I_0\cos\varphi$
-170°...0°...+60° & $I_0\cos\varphi$
-170°...0°...+88° & $I_0\cos\varphi$
-170°...0°...+78° & $I_0\cos\varphi$
-170°...0°...+68° & $I_0\cos\varphi$</td></tr>
</table>

3. Earth-fault stages with $I_0\cos\varphi$ function on the positive and the negative sector

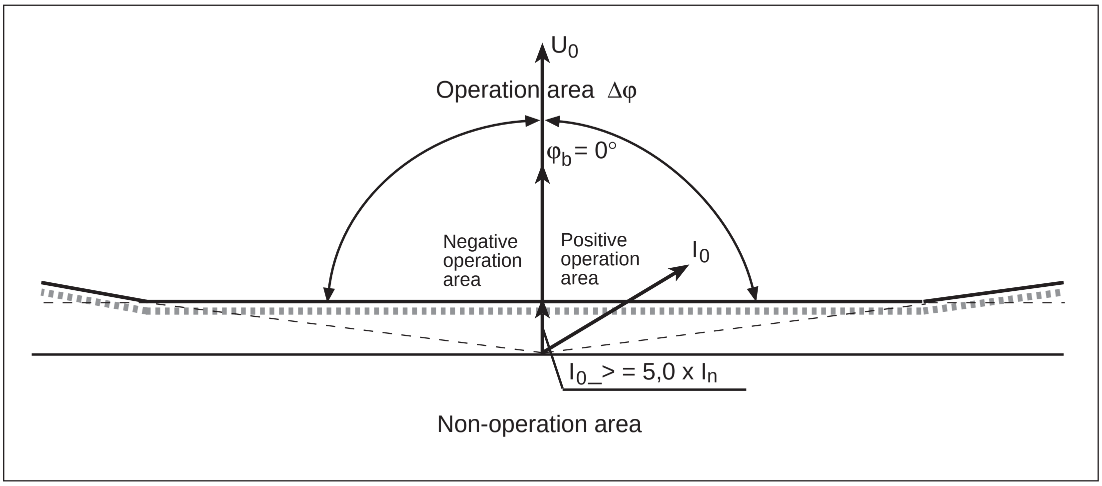


Fig.3. Example of operation area -80° & $I_0\cos\varphi$...0°...+80° & $I_0\cos\varphi$, when the basic angle $\varphi_b = 0°$.

Table 3: Operation areas to be selected with switches SGF_ and SGX at $I_0\cos\varphi$ function on the negative and the positive sector.

Switch			Earth-fault stages with $I_0\cos\varphi$ function on both sectors, SGX/3 = 0 & SGX/4 = 1	
			Earth-fault stages set to operate on normal earth faults, SGF3/6 = 0	Io2> stage set to operate on intermittent earth faults, SGF3/6 = 1
			Stage $I_{01}>$	
SGF3/5			SGF3/6 = 0	SGF3/6 = 1
0			-80° & $I_0\cos\varphi$...0°...+80° & $I_0\cos\varphi$	-80° & $I_0\cos\varphi$...0°...+80° & $I_0\cos\varphi$
1			-88° & $I_0\cos\varphi$...0°...+88° & $I_0\cos\varphi$	-88° & $I_0\cos\varphi$...0°...+88° & $I_0\cos\varphi$
			Stage $I_{02}>$	
SGF3/5	SGX/5	SGX/6	SGF3/6 = 0	SGF3/6 = 1
0	0	0	-80° & $I_0\cos\varphi$...0°...+80° & $I_0\cos\varphi$	-80° & $I_0\cos\varphi$...0°...+80° & $I_0\cos\varphi$
0	1	0	-80° & $I_0\cos\varphi$...0°...+80° & $I_0\cos\varphi$	-70° & $I_0\cos\varphi$...0°...+70° & $I_0\cos\varphi$
0	0	1	-80° & $I_0\cos\varphi$...0°...+80° & $I_0\cos\varphi$	-60° & $I_0\cos\varphi$...0°...+60° & $I_0\cos\varphi$
1	0	0	-88° & $I_0\cos\varphi$...0°...+88° & $I_0\cos\varphi$	-88° & $I_0\cos\varphi$...0°...+88° & $I_0\cos\varphi$
1	1	0	-88° & $I_0\cos\varphi$...0°...+88° & $I_0\cos\varphi$	-78° & $I_0\cos\varphi$...0°...+78° & $I_0\cos\varphi$
1	0	1	-88° & $I_0\cos\varphi$...0°...+88° & $I_0\cos\varphi$	-68° & $I_0\cos\varphi$...0°...+68° & $I_0\cos\varphi$

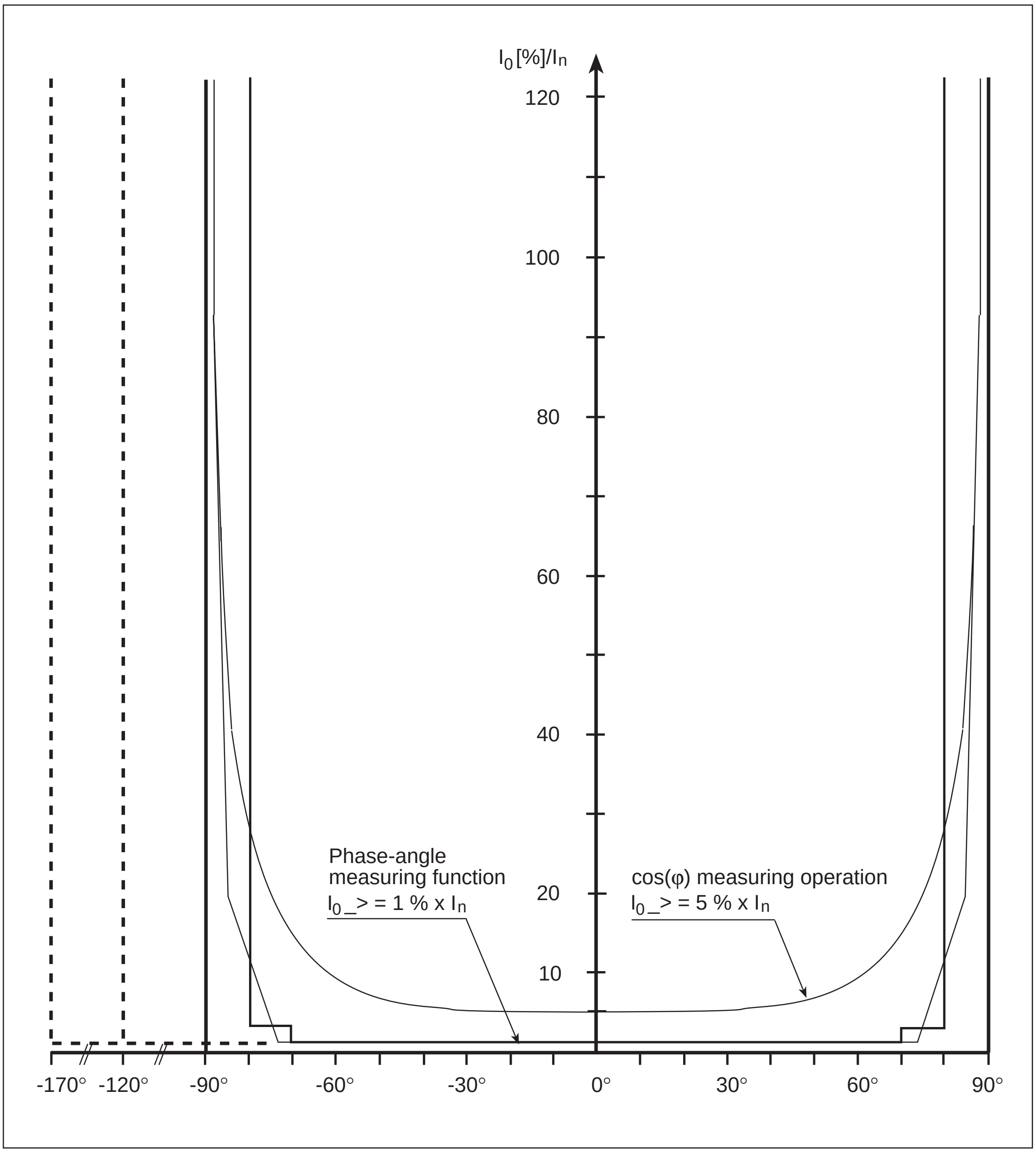


Fig. 4. Overview of operation areas of the directional earth-fault stages, when the basic angle φ_b = 0° and the start current I_0_> = 1.0 % x I_n at phase-angle measuring function and 5.0 % x I_n at I_0cosφ measuring operation.

Technical data affected by versions SW 089 E, F

Operation principles of earth-fault stages for I_{01}> or I_{02}>

Operation sector $\Delta\varphi$	SW: - 089 C, D:	±80°, ±88°
	- 089 E:	±80°, ±88°, -120°
	- 089 F:	±80°, ±88°, -120°, -170° (+60°, +68°, +70°, +78°)*
		*) The values in brackets apply to the I_{02}> stage when SGF3/6=1
Operation principle	SW: - 089 F:	Phase-angle measuring function or $I_0\cos\varphi$ function

High-set earth-fault stage I_{02}>

Operate time, t_{02}>		
- SGF3/6=0	SW: - 089 C, D, E:	0.1s
	- 089 F:	0.1, 1.5, 2.0, 2.5 s
- SGF3/6=1,	SW: - 089 C, D, E:	0.75 s
	- 089 F	0.75, 1.5, 2.0, 2.5 s

Recommendation for configuring the module SPCJ 4D44 SW 089 F

To maximize the functionality of the module at earth faults apt to develop into intermittent faults, the following module settings are recommended:

Definition of setting values:
- The residual voltage U_0> is calculated as normal.
- The start current for the earth-fault stage I_{01}> is calculated as normal.
- The start current recommended for the earth-fault stage I_{02}> exceeds the start current of the I_{01}> by 10%.
- The operate time for to1> is calculated as normal.

Programming of switches:

SGF2/1	= 1	basic angle, φ_b = 0°, for resonant-earthed networks
SGF2/2	= 1	- " -
SGF3/5	= 0	operation area ±80°
SGF3/6	= 1	I_{02}> intermittent function
SGF3/7	= 1	negative operation area of stages I_{01}> and I_{02}> -170°
SGX/1	= 0	operate time t_{02}> = 0.75 s
SGX/2	= 0	- " -
SGX/3	= 1	$I_0\cos\varphi$ function on the positive operation area
SGX/4	= 0	- " -
SGX/5	= 1	positive operation area of stage I_{02}> +70°
SGX/6	= 0	- " -

Other settings:
Other module settings have to be adapted to the calculations made for the line and the network.

Other issues to consider

Reactor compensation:
To obtain maximum protection for both the faulted line and the healthy lines, a compensation degree of 5…10% (overcompensated) is recommended.

Residual voltage relay:
To avoid unselective tripping by the residual voltage relay, the operate time of the relay must be long enough compared to the operate times of the directional earth-fault relays of the feeders. At an intermittent earth fault, the earth-fault stages of the faulted line may be delayed. For this reason, the operate time of the earth-fault stage of the faulted line should be at least 5 s for the residual voltage relay (or at least twice the operate time of the directional earth-fault stages).

Local recommendations and regulations:
In this document we have paid no attention to local recommendations and regulations, which have to be considered by the user.

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